DIRECTOR OF INDUSTRIES.
Bengal

Industrial Alcohol

Its Manufacture and Uses

A Practical Treatise

BASED ON DR. MAX MAERCKER'S "INTRODUCTION TO DISTILLATION" AS REVISED BY
DR. DELBRÜCK AND DR. LANGE

DIRECTOR OF INDUSTRIES
Bengal

Comprising RAW MATERIALS, MALTING, MASHING AND YEAST PREPARATION, FERMENTATION, DISTILLATION, RECTIFICATION AND PURIFICATION OF ALCOHOL, ALCOHOLOMETRY, THE VALUE AND SIGNIFICANCE OF A TAX-FREE ALCOHOL, METHODS OF DENATURING, ITS UTILIZATION FOR LIGHT, HEAT AND POWER PRODUCTION, A STATISTICAL REVIEW, AND THE UNITED STATES LAW

BY
JOHN K. BRACHVOGEL, M. E.

WITH SPECIAL CHAPTERS BY
CHARLES J. THATCHER, PH.D. (LEIPSIC)

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PREFACE.

WHILE many phases of the fermentation and distillation industries have attained a high plane of development in this country, the question of denatured alcohol for commercial purposes has played no part in our economic and industrial evolution, owing to the prohibitive tax with which spirit has hitherto been burdened. When Congress passed the Act of June 7th, 1906, which permits the use of tax-fee, denatured alcohol, and which became effective on the 1st of January, 1907, the American agricultural and manufacturing producers were given a new and vastly promising field of endeavor to exploit. Few are the industries which are not benefited by a tax-free industrial alcohol. The manufacturers of countless commodities are provided with an effective means for the reduction of operating cost, while the farmer is offered a practically unlimited outlet not only for the produce of his land, but as well for vast quantities of material, which has hitherto been valueless waste. The American literature on this subject is a very limited one, and the present volume, it is hoped, will supply a needed treatise on industrial alcohol, both for educational purposes and for use in practice by the distiller and consumer.

The work is based on Dr. Max Maercker's "Introduction to Distillation," as revised by Dr. Delbrück in collaboration with Dr. Lange. The "Introduction" was intended specifically as such for Dr. Maercker's "Hand Book of Distillation," recognized in Germany and the world over as one of the most comprehensive and authoritative works of its character. The "Introduction" was designed for the use of students and practical distillers, and was, therefore, written as far as possible in non-technical language. The present book comprises practically the entire text of the "Introduction," but so extended, revised and enlarged that the resulting volume constitutes an intermediate work between the "Introduction" and the "Hand Book" of Dr. Maercker. The introductory section on the industrial value of tax-free alcohol, as well as those sections dealing with the denaturing of alcohol, its use for lighting and heating, and the statistical data, were written especially for this book by Dr. Charles J. Thatcher. The discussion of alcohol for fuel power purposes, based largely upon the investigations of Professor Eugen Meyer, of Berlin, is my own. Acknowledgments are due to Mr. Joseph H. Allen and Mr. Whidden Graham, of the Committee of Manufacturers, for extended information regarding domestic and commercial devices for the utilization of denatured alcohol, as well as for valuable data in regard to the benefits to be derived from tax-free alcohol, here and abroad, and the conditions obtaining in its use.

The great European source of industrial alcohol is the potato. Up to the present time this vegetable has not come into general utilization for a similar purpose in this country, and the present sources of spirit in the United States are found in the various grains and in certain sacchariferous raw materials, such as the sugar beet and molasses. The peculiar suitability of the potato for alcohol production on a large scale will doubtless soon bring about its wide employment here, too, for this purpose. The present volume deals almost exclusively with the manufacture of spirit from potatoes and grain, while the other suitable raw materials, the utilization of which is more limited, have, of necessity, been dealt with in a very brief manner only.

The principle of the natural pure yeast culture has been developed mainly in Germany, where the science of fermentation has attained a level rivaled in but few of the other nations. Dr. Delbrück, one of the foremost German fermentologists, has been closely identified with the development of this process, which is of the very greatest importance in successful distillation. In this treatise the principle of the natural pure yeast culture in accordance with the best German practice, has been discussed as thoroughly as possible, in order to emphasize the rule, as stated by Dr. Delbrück, that, "the best results can be attained only when the natural culture is combined with the absolutely pure culture of the yeast."

Needless to say the German publishers have authorized the use for all English-speaking countries of Dr. Maercker's "Introduction to Distillation."

JOHN K. BRACHVOGEL.

New York, February, 1907.

TABLE OF CONTENTS.

The Industrial Value of Tax-free Alcohol and What it Means for Our Agricultural Interests.

The Increasing Use of Small Motors and Demand for Cheap Liquid Fuel. 2
Insufficiency of the Gasoline Supply. 4
The Possibility of Practically Unlimited Alcohol Production in this Country. 5
The Advantages of Alcohol as Fuel 6
Efficiency of Alcohol Motors. 8
Alcohol in the Arts and Manufactures 11
What the Past Teaches Us About the Industrial Use of Alcohol 12
Summary of the Benefits of Industrial Alcohol to Agriculture . 14
General Advice to Agriculturalists 16
Summary of the Processes in Spirit Manufacture 19

Part I.—Starch, How it is Formed, its Characteristics, and the Changes it Undergoes in Spirit Manufacture

I. The Forms of Starch. 22
II. The Composition and Formation of Starch 24
III. The Characteristics of Starch. 25
IV. Starch Reactions. 28
V. The Behavior of Starch With Respect to Acids and Diastase 30

Part II.—The Enzymes or Ferments

I. General Introduction. 32
II. Classification of the Enzymes According to Their Actions 33
1. Carbohydrate Enzymes. 33
2. Proteolytic Enzymes 33
3. Zymase 34
4. The Oxydases 34
5. The Lipases 34
III. The Enzymes of Greatest Importance in the Distillation Processes 34
1. Diastase 34
2. Peptase 36
3. Zymase 37

Part III.—The Products of Fermentation

I. Alcohol 41

II. Carbonic Acid 44
III. The By-products of Fermentation 44

PART IV.—THE STARCHY RAW MATERIALS IN SPIRIT MANUFACTURE.

I. The Potato 46
  1. The Composition and Qualities of Potatoes 46
  2. Phenomena During the Storage of Potatoes 50
  3. The Investigation of the Potato with Regard to Starch 52
  4. Determination of the Dry Substance of Potatoes 57
  5. Dry Potatoes 58
II. Barley 59
III. Rye 60
IV. Corn or Maize 61
V. Oats 63
VI. Wheat 63
VII. Rice 64
VIII. Other Raw Materials Used in Spirit Manufacture 64

SACCHARIFEROUS RAW MATERIALS

A. Sugar Beets 65
B. Molasses 66
C. Various Other Sacchariferous Raw Materials 67

PART V.—THE PREPARATION OF THE MALT.

I. The Purpose of the Malt in Distillation 69
II. Materials Suitable for Malt Preparation 70
III. Water in Malting and the Properties it Should Possess 73
IV. Washing the Barley 75
V. The Steeping Vat and the Operation of Steeping 77
VI. The Arrangement of the Malt House 83
VII. The Processes of Germination 86
VIII. The Treatment of the Grain Upon the Malting Floor 92
IX. The Preparation of Long Malt 94
X. The Preparation of Felted Malt 98
XI. Practical Data for Malting 99
XII. The Preparation of Malt from Oats, Wheat, Rye, and Corn 100
  1. Rye and Wheat Malt 100
  2. Oat Malt 102
  3. Corn Malt 104
  4. Malt from Fungi 105
XIII. The Preservation of Malt Through Drying 106
XIV. The Quantities of Malt Necessary for Sugar Formation 108
XV. Comminution of the Green Malt 109
  1. Malt Crushers 109

2. Malt Milk Apparatus 111

PART VI.—STEAMING THE RAW MATERIAL.

I. The Working of Potatoes 112
  1. Washing the Potatoes 112
  2. Steaming the Potatoes 114
    A. Steaming at Ordinary Pressure 115
    B. Steaming Under High Pressure 116
  3. High Pressure Apparatus 117
    A. The Older Systems 117
    B. The Henze Steamer 117
    C. Proportions of the Henze Apparatus 122
  4. The Devices Used with the Henze Steamer 125
    A. The Exhauster 125
    B. The Blow-out Devices of the Henze Steamer 128
    C. Mash Mills 131

II. Steaming Corn, Grain and Other Raw Materials 132
  A. Working Corn by the Old Method 132
  B. Working Corn Under High Pressure 135
    1. Working Corn in the Whole Grain 136
    2. The Working of Grist 139
  C. Working Corn With Strong Mineral Acids 142
  D. Working Corn by Means of Compressed Air 143
  E. Working Malted Corn 143
  F. Working Mixtures of Potatoes and Corn 144
  G. Working Rye 145
    1. Working Rye at Ordinary Pressure 145
    2. Working Rye at High Pressure 147
    3. Steaming Mixtures of Rye and Potatoes... 148

PART VII.—THE MASHING PROCESS AND APPARATUS.

I The Methods of Operation.
  1. The Purpose of the Operation 150
  2. Principles to be Considered in Mashing 150
  3. Mashing in Practice 153
  4. Mashing Barley, Rye, Wheat, and Oats 156
  5. Mashing Sacchariferous Raw Materials 159

II. The Apparatus Used in Mashing 160
  1. Preparatory Mash Vats Without Water Cooling.... 161
  2. Water-cooled Preparatory Mash Vats 163

III. Clearing the Mash 173

IV. The Power Necessary to Drive the Machinery of the Distillery 182

V. Coal Consumption in the Distillery 184

VI. Investigation of the Sweet Mash by Saccharometry 185
VII. Other Tests for the Sweet Mash 190

Part VIII.—Fermenting the Mash.

I. Cooling to the Fermenting Temperature 204
II. Alcoholic Fermentation as it is Understood To-day. . . 208
III. The Historical Development of Fermentation 209
IV. Yeast the Exciter of Fermentation 212
V. Pure Yeast Cultivation 216
VI. The Yeast Races 222
VII. Fermentation Exciting Mold Fungi and Bacteria 226
VIII. The Development of Heat During Fermentation 227
IX. Substances Suitable for the Nutrition of the Yeast. ... 228
X. The Fermenting Temperature and the Substances Injurious and Favorable to Fermentation 229
XI. Substances Capable of Fermentation 230
XII. Substances Arising During Fermentation 231
XIII. Schizomycetes (Bacteria) in the Distillery 232

Part IX.—The Preparation of Artificial Yeast in the Distillery.

I. The Preparation of the Yeast Mash 236
  1. The Preparation of Yeast With Green Malt. 240
  2. The Preparation of Yeast With Kiln-dried Malt .. 242
  3. The Preparation of Yeast with Avoidance of Dead Periods 242
  4. The Preparation of Emergency Yeast 242
  5. The Preparation of Hop Yeast 243
  6. Partenheimer's Mash Yeast 244
II. Souring the Yeast Mash 244
III. The Use of Technical Acids to Replace Souring Induced by Fermentation 247
IV. Sterilization of the Yeast Mash by Means of Heat ... 251
V. Cooling the Yeast Mash 253
VI. The Addition of the Mother Yeast to the Yeast Mash. .. 256
VII. Fermentation and Yeast Development in the Yeast Mash 258
VIII. Removal of the Mother-Yeast 260
IX. The Use of Ripe Yeast for Pitching the Sweet Mash .. 261
X. Special Directions for Yeast Preparation 262
XI. The Investigation of the Yeast 264

Part X.—Fermentation in Practice.

I. The Various Fermenting Periods 266
  1. Pre-fermentation 266
  2. The Chief Fermentation 267
  3. The After-fermentation 268

II. Movable Vat Cooling 269
III. Concentrated Mashing and Its Advantages 273
IV. Reviving the Mash with Water 274
V. The Value of Longer Fermentation Periods for Concentrated Mashes 275
VI. Foaming Fermentation 275
VII. The Fermenting Room and Vats 278
VIII. The Water Consumption of the Distillery 281
IX. The Investigation of the Fermented Mash 281
    1. The Determination of the Degree of Fermentation 281
    2. The Determination of the Acidity 285
    3. The Determination of the Alcohol Content of the Fermented Mash 286
X. The Alcohol Yield Obtained in Practice 287
XI. The Amylo Process 289

PART XI.—DISTILLATION AND RECTIFICATION

I. General Information 293
II. Simple Distillation 296
III. Dephlegmation 297
IV. Compound Distillation, Rectification, and Dephlegmation 300
    1. Periodical Distilling Apparatus 300
    2. Continuous or Uninterrupted Apparatus 303
        A. Apparatus for the Production of Raw Spirit. 304
        B. The Modern Dephlegmator 309
        C. Apparatus for the Production of High Percentage Spirit Direct from the Mash 315
V. Cleaning the Distilling Apparatus 316
VI. Rectification and Purification of Alcohol 317
VII. Rectifying Apparatus 319
VIII. Substances Used for the Purification of Alcohol During Rectification 324
IX. Alcoholometry, the Investigation of the Spirit Obtained With Regard to Its Content of Pure Alcohol 326
PART XII.—THE ARRANGEMENT OF THE DISTILLERY 335
PART XIII.—THE SPENT WASH 337

PART XIV.—THE DENATURING OF ALCOHOL.

I. The Purpose of Denaturing 343
II. Denaturing Regulations 344
    1. United States 344
    2. Germany 345
    3. England 348
    4. France 349

5. Sweden 352

PART XV.—ALCOHOL FOR THE PRODUCTION OF POWER.

I. Comparative Efficiencies of Gasolene, Kerosene, and Alcohol Motors 359
II. The Alcohol Motor 362

PART XVI.—HEATING WITH ALCOHOL.

I. Economy of Alcohol Fuel 374
II. Nature of the Fuel 375
III. Heating Appliances 377

PART XVII.—ILLUMINATION WITH ALCOHOL.

I. The Alcohol Lamp 393
II. Advantages of the Alcohol Lamp 397

PART XVIII.—STATISTICS OF ALCOHOL PRODUCTION.

I. United States 399
II. Germany 401
III. France 405
IV. Great Britain 406
V. Belgium 407

APPENDIX.

Specifications for Methyl Alcohol and Benzine Submitted for Approval as Denaturing Materials 411
Regulations and Instructions Concerning Denatured Alcohol, Under Act of Congress, June 7, 1906 416
I. Denaturing Bonded Warehouses 418
II. Dealers in Denatured Alcohol and Manufacturers Using Denatured Alcohol 451
III. Special Denaturants 461
IV. Alcohol Recovered, Restored, and Redenatured 482
V. Restoring and Denaturing Plants 493

DIRECTOR OF INDUSTRIES
Bengal

INDUSTRIAL ALCOHOL

ITS MANUFACTURE AND USES

THE INDUSTRIAL VALUE OF TAX-FREE ALCOHOL AND WHAT IT MEANS FOR OUR AGRICULTURAL INTERESTS.

THERE is no more important factor in material progress than the supply of fuel. Its price is a vital matter to all classes of society, and to every industry from agriculture to steel manufacture. For even the farmer, who has been the last to substitute power-driven machinery for manual labor, has felt this the universal impulse of the age and, as will be shown, is increasingly demanding fuel for this purpose as his woodland supply disappears.

The position of the agricultural industry is in some respects a characteristic one; like nearly all the others, it may soon be dependent on monopolies for fuel for power generation. For there have been practically no other sources of power in this country than coal and oil, and the control of these has passed into the hands of a few individuals. But Congress, when it provided for the denaturing of alcohol after January 1, 1907, did for the agricultural industry more than it has been able to do for any other; it made possible thereby the new use of its products, and in vast quantities, for the manufacture of a fuel, and gave the farmer a chance to compete with the coal and oil industries as a producer of a fuel to drive his own machinery as well as that of other industries.

This new use of farm products was made possible solely by the removal of the tax of $2.07 per gallon on alcohol which has been denatured, that is, rendered unfit for internal use. Grain alcohol, even for industrial uses, has for many years cost on an average $2.50 per gallon in this country, almost ten times as much as it should, and only because of this tax. The removal of the latter means that denatured alcohol will soon cost at least not more than gasolene. It insures, at this price, the successful competition of alcohol with gasolene as a fuel for internal combustion engines; the great advantages of alcohol for power generation especially in small units has long been a demonstrated fact.

The Increasing Use of Small Motors and Demand for Cheap Liquid Fuel.

That the farmer is rapidly adopting the use of motor-driven machinery is the opinion of competent authorities. The advantages of these engines are so obvious that it will not be long before every farmer will have to use one in all the various operations of the farm. Leading manufacturers of agricultural implements are making arrangements to manufacture motors of this class on a large scale, and experiments are being made by the prominent thresher manufacturing companies to produce a perfect portable farm engine of this type. They await favorable motor fuel conditions alone to adopt it entirely. At the hearing before the Committee on Ways and Means of the House of Representatives, held February 8 and 9, 1906, J. C. Warnes, representing the International Harvester Company, stated that at the present time the general utility of the small engine on the farm is recognized more by the agriculturist than ever before. He finds it useful, for example, in pumping water, grinding feed, threshing grain, shredding fodder, sawing wood, and operating churns and cream separators. The application of alcohol can even be readily extended to tractors, with favorable prices on fuel, so that it will not be long before power-driven grain harvesters, mowers, plows, corn harvesters, cultivators, and many similar farm implements may take the place of those now in use and thereby effect a considerable saving in the cost and maintenance of an extra team.

This refers, of course, to the future use of internal combustion motors on the farm. In these the fire-box is in the cylinder itself, where a gaseous mixture is exploded; its situation is not external as in the generation of steam from coal. The actual and widespread use in other lines of this kind of engine is well known. The authority just quoted stated that 100,000 is a conservative estimate of the number of stationary engines of this type manufactured in 1905 in this country. To this should be added at least 25,000 engines annually manufactured for automobile purposes, so that with those already in use, not less than 300,000 explosion motors are now in use in this country. These engines will probably average 8 horsepower, and each engine will consume in a day of ten hours approximately 10 gallons of gasolene. If there are 300,000 engines in this country running on this basis for one day it would mean a consumption of 3,000,000 gallons per day.

This estimate of Mr. Warnes is largely illustrative, but it is in accord with that of other authorities. It means that the total demand for gasolene, benzene, etc., in this country will soon exceed 1,000,000,000 gallons annually. To this is to be added the quantity to be exported each year, which in 1904, according to official figures, was 24,989,422 gallons. In order, therefore, to supply our own demand for gasolene, etc., and to retain the volume of our export trade in these articles, we will need in the near future not less than 1,025,000,000 gallons annually.

Insufficiency of the Gasolene Supply.

Gasolene is a by-product of the oil industry, and less than 5 per cent of it is obtained from eastern crude petroleum and practically none from that found in California, Texas, and other states, from which the largest part of our oil supply now comes. But the demand for kerosene and the heavier oils which comprise the principal products of petroleum does not begin to increase at the same rate as the demand for gasolene; and the rate of increase of this demand is retarded only by the high price of this, the only fuel hitherto available for motors.

On the other hand, the statistics of production show a decrease during 1905 as compared with the previous year of 4,720,700 barrels of petroleum in the yield from the oil fields of Pennsylvania, Ohio, and Indiana. This, allowing 42 gallons to the barrel, means a falling off in one year of 198,269,400 gallons of the grade of petroleum from which gasolene is obtained, or a decrease of nearly 10,000,000 gallons of gasolene in the last year, computed as 5 per cent of the decreased crude oil yield. In 1904 the total quantity of gasolene, benzene, naphtha, etc., obtained from crude oil in the United States, was 244,074,139 gallons. This is but one-fourth of the quantity which, it is estimated, we will soon need annually to run our internal combustion engines eight hours a day, and this annual yield may continue to decrease at the rate of 10,000,000 gallons per annum as it did last year.

The price of gasolene has doubled in the past ten years, and it is evident from the above that in a short time it will reach a prohibitive price to all but wealthy owners of automobiles and motor boats.

The Possibility of Practically Unlimited Alcohol Production in This Country.

The decrease in our gasolene supply and the accompanying increase in the demand and price thereof constitute an all-sufficient cause for the substitution of some liquid fuel for gasolene in the near future. Alcohol provides such a substitute, and a satisfactory one. In the first place, it can be produced in almost unlimited amounts in this country. It can be obtained from all substances containing starch, sugar, or cellulose, such as potatoes, corn, corn cobs and stalks, grains, cane and beet sugar refuse and molasses, and even from grape skins, lees of wine, and sawdust. From potatoes 275 gallons of alcohol are obtained per acre. Germany, in the campaign year, 1904-5, obtained from this crop alone about 80,000,000 gallons of alcohol. We should have no trouble in making much more than that quantity yearly from our potato crop, especially in favorable years like the last. Our corn crop of 1905 is estimated to have been in round numbers 250,000,000 bushels more than in 1904. It has been absolutely established that 2.6 gallons of 94 per cent commercial alcohol can be obtained from one bushel of corn, which would give *650,000,000 gallons of alcohol from one year's increase in our corn crop.* This is about 34,000,000 gallons of alcohol more than the total quantity of kerosene and gasolene consumed here last year, which was about 616,000,000 gallons.

With regard to the amount of spirit which can be obtained from corn stalks alone, the Hon. James Wilson, Secretary of Agriculture, said at a recent Congressional hearing:

"The stalks of Indian corn, at the time when the grain is sufficiently hardened to be perfectly sound, when harvested, contain a large quantity of starch. If the stalks of Indian corn could be utilized at that time for the manufacture of alcohol, they would produce a quantity which would be almost incredibly large. There would be approximately 10 tons of stalks to the acre of Indian corn, yielding 50 bushels the acre, or 20,000 pounds, and of this at least 12 per cent, or nearly 2,400 pounds, is fermentable matter, 45 per cent of which can be recovered as alcohol, equivalent to 1,080 pounds of absolute alcohol, or approximately 170 gallons of commercial alcohol. The average yield of Indian corn is only about half the above, but the heavier corn lands of the country that would be used for growing corn for alcohol average easily 50 bushels to the acre. It is safe to say that the average amount of sugar and starch which goes to waste in the stalks of Indian corn annually would make 100 gallons of commercial alcohol per acre. When we consider the vast number of acres cultivated in Indian corn, approximately 100,000,000, it is seen that the quantity of alcohol that is lost in the stalks is so large as to be almost beyond the grasp of our conception."

We have therefore the authority of the Secretary of Agriculture for the statement that from corn stalks alone we may be able to obtain one hundred million gallons of alcohol yearly. Even though it be found that this immense source cannot be utilized, no further evidence of the ability of this country to produce sufficient alcohol to meet the demand for liquid fuel is necessary.

The Advantages of Alcohol as Fuel.

That alcohol is suitable for much of the work which gasolene and gas are now doing has already been demonstrated. In fact in many respects it is much superior. It is clean, odorless, and its vapor is not inflammable unless closely confined, so that naked lights can be used around a machine without danger of accident or explosion. It has a higher boiling point than gasolene, and there is therefore less loss by evaporation and less danger of accidental ignition, especially in warm weather. Furthermore, the combustion of alcohol is always so perfect that there is practically no smoke, soot, or disagreeable odor such as there usually is from gasolene motors. Another property of alcohol which makes it much safer than gasolene, and especially for household use, is that it mixes freely with water, with which, therefore, it can be diluted easily when accidentally ignited and thereby rendered incombustible. Gasolene and kerosene, on the other hand, float on water and spread the burning material when attempts are made to extinguish it in this way. Furthermore, the flame of gasolene is highly luminous, for it is filled with particles of incandescent carbon. A mass of burning gasolene radiates heat, therefore, and will set fire to things some distance removed. Alcohol, on the other hand, gives a faint, blue, nearly non-luminous flame. It does not radiate heat to any great extent, and for these reasons accidental fires therefrom do not spread rapidly. It must heat some other substance in order to radiate its heat, just as the blue gas flame does the asbestos of a gas log which is to be used for heating.

Still another and most important fact in connection with the use of alcohol as a fuel is that there is absolutely no exhaustion of those elements of soil fertility which are essential to the welfare of our agricultural industry. Commenting on this, Dr. H. A. Wiley, of the Department of Agriculture, testifies as follows: "The farmer can grow any amount of starch and sugar that may be wanted for any purpose in the world. There is no limit to the amount of sugar and starch which the farmers of this country can grow, and not a pound of starch or sugar takes one element of fertility from the soil."

In the exportation of alcohol, therefore, we will not send abroad the fertile constituents of our soil as we do now in the form of grain and meat. Eminent scientists have long pointed out the wastefulness of this system. Alcohol, on the other hand, is composed only of carbon, hydrogen, and oxygen, and the products of its combustion are as gaseous and liquid combinations of the elements just mentioned (kept in universal distribution over the globe). Nitrogen, phosphates, and all the other scarcer elements needed for vegetable growth are returned to the original soil by the wash or residue from alcohol manufacture. When we add to these indisputable advantages the fact that heavy crops can be stored for years in non-perishable form as alcohol, and that it can be conveyed by pipe lines even more easily than petroleum products, the adaptability of alcohol fuel is more than sufficiently demonstrated.

Efficiency of Alcohol Motors.

The hitherto prohibitively high price of alcohol has prevented much experimental investigation of the alcohol motor in this country. Prof. Charles E. Lucke has conducted a series of experiments at Columbia University in New York for the Department of Commerce and Labor, which are embodied in a report published by that department. Prof. Elihu Thomson likewise has tested alcohol motors of German manufacture in the works of the General Electric Company, at Lynn, Mass. In reporting upon the same to the Committee of Ways and Means he states: "It may be mentioned here that our experiments developed the fact that alcohol is suitable as a motor fuel even when it contains as much as 15 per cent of water. Notwithstanding the fact that the heating value of alcohol or the number of heat units contained is much less than that in gasolene, it is found by actual experiment that a gallon of alcohol will develop substantially the same power in an internal-combustion engine as a gallon of gasolene. This is owing to the superior efficiency of operation when alcohol is used. Less of the heat is thrown away in waste gases and in the water jacket.

"The mixture of alcohol vapor with air stands a much higher compression than one of gasolene and air, without premature explosion, and this is one of the main factors in giving a greater efficiency. It follows from this that, with alcohol at the same price as gasolene, the amount of power developed and the cost of the power will be relatively the same so far as fuel itself is concerned, but on account of the higher efficiency of the alcohol less cooling water is required, or a less percentage of the heat of combustion is communicated to the cylinder walls of the engine. The exhaust gases from the alcohol engine carry off less heat. They are cooler gases.

"It is well known that the exhaust gases from a gasolene or kerosene engine are liable to be very objectionable on account of the odor. In our test of the Deutz alcohol engine here there was absolutely no such objection with alcohol fuel, the exhaust gases being but slightly odorous, or nearly inodorous, and what odor there was was not of a disagreeable character."

This motor was sent to Cuba, where cheap alcohol is now sold for industrial purposes at about 10 cents per proof gallon. The practical use of such motors there is demonstrated by the report of H. T. Squires, United States Minister to Cuba in 1904. He states, writing from Matanzas, a city of 40,000 inhabitants:

"The alcohol motor pump is of German manufacture, and cost, complete with installation, $6,000. This motor pump is a 45-horse-power machine, and is operated at a fuel cost of about 40 cents an hour, or $4 a day of ten hours, pumping 1,000,000 gallons of water.

"As alcohol is very cheap (10 cents a gallon), the running expenses of these motors are at a minimum. The Germans are selling in Cuba many such motors for electric-lighting and water plants at very low prices. One firm has a contract to put in an alcohol motor pump at Vento, for use in connection with the Habana water supply, which is expected to develop 180 horse-power, to cost, with installation, about $25,000, and to pump 1,000,000 gallons an hour at a fuel cost of $1.60. The same firm has installed an electric plant alcohol motor of 45 horse-power which supplies 138 lights (Nernst lamps) at a fuel cost of 5 cents an hour."

This is conclusive evidence of the efficiency of alcohol in stationary engines. There have been numerous trials of it in motors for moving vehicles or locomobiles in Europe, which demonstrate its adaptability and efficiency for such uses. In France, Messrs. Brille, Chauveau, Perisse, Ringelmann, Sorel, Trillat, De la Valette, and Dupays have demonstrated the superiority of alcohol over other liquid fuels.

Henry Dupays, one of the foremost French experimenters in this field, states in an article in the Engineering Magazine of February 14, 1904: "In the northern circuit a machine burning carbureted alcohol attained a mean speed of 72 kilometers (44.7 miles) per hour, on a good road of 924 kilometers. A Panhard motor using the same fuel made an average of 90 kilometers (55.9 miles) per hour, on the first stage of the Paris-Vienna race. Such a high speed has never before been reached on the Paris-Belfort run. The adaptability of alcohol to this use therefore cannot be doubted."

There are not wanting actual tests of the efficiency of alcohol motors on the farm itself. In England, where most of the farm land is practically level, gasolene and even kerosene engines have been used for some time for plowing, and recently Mr. Daniel Albone, of Biggleswade, Bedfordshire, inventor of the first agricultural engine of this type, has tried alcohol. In a comparative test of the three fuels the same engine and carbureter were used with only a slight attachment and no alterations. All tests were made on the same soil and on the same day. The results in surface plowed were:

With 2 gallons of gasolene, 3 roods of land.

With 2 gallons of kerosene, 2 roods, 35 poles.

With 2 gallons of alcohol, 2 roods, 25 poles.

Alcohol, therefore, as can be easily computed is only 1-8 less efficient than gasolene and 1-11 less than kerosene for plowing land, on the basis of the figures given.

In Germany, Prof. E. Meyer has made the most extensive tests which are embodied in a report to the German Agricultural Society in 1902. He found that taking the price in Germany of alcohol at 2¼ to 2⅜ cents, petroleum at 2½ cents, and benzine at 2¾ cents per pound, the relative costs per horse-power hour were:

	Full Load	Half Load.
Alcohol	7.3—7.6	10.1—10.6
Benzine	7.1	10.4
Petroleum	7.3	10.8

These trials would seem to warrant the immediate adoption of alcohol as a fuel for locomobiles. Notwithstanding this, the use of alcohol motors for such purposes in Europe has been very small and below expectations. The cause of this is doubtless to be found in the difficulty always attending the development of a new type of engine. Many of the practical trials have been made with engines designed primarily for gasolene. While it has been shown that the same explosion engine can use gasolene and alcohol interchangeably, the specially designed engine develops the highest economy and is most satisfactorily operated.

Alcohol in the Arts and Manufactures.

It must not be forgotten that the increased demand for tax-free alcohol will not come alone from its use in explosion motors. Denatured alcohol will be used in a short time as it is in England and in continental Europe, in a great variety of industries. For example, in making artificial lubricants, furniture polish, finish, varnish, lacquers, enamels, celluloid, zylonite, aniline colors, dyeing and preparing colors, dissolving resins for hat makers, manufacture of collodion, goldbeaters' skin, filling spirit levels, floating mariner's compasses, extracting vegetable alkaloids, making vegetable extracts (dry), manufacture of transparent soap, quick-drying paints, preserving objects of natural history, chemical and anatomical research, in making sulphuric ether, chloral hydrate, chloroform, fulminating powder and explosives, liniments of soap, synthetic camphor, aconite and belladonna, hypersperm oil, artificial silk, electrodes for storage batteries, photographic emulsions, lanolin, vinegar, etc. For such purposes there were used in Germany in the year 1904-5 5,760,000 gallons of incompletely denatured alcohol, and 26,000,000 gallons of completely denatured alcohol. Our industries making many of these articles have been crippled because of the hitherto high price of grain alcohol, and we can safely predict that many million gallons will soon be wanted yearly for such purposes in this country.

What the Past Teaches Us About the Industrial Use of Alcohol.

The extent to which tax-free alcohol will be used in this country cannot safely be judged from the progress of the industry in other countries. No great, progressive, agricultural nation has ever given it a thorough trial. England has had tax-free alcohol since 1855; but it is not an agricultural country and much of her alcohol has been imported. From Germany even, in which the conditions most closely resemble those here, no satisfactory conclusions can be drawn. Tax-free alcohol has been in use there since 1887. During that time the yearly consumption of completely denatured alcohol has increased from 3,600,000 to 26,000,000 gallons in 1904, or over seven times in seventeen years. The retail selling price, as recorded in the Daily Consular and Trade Reports of Monday, September 10, 1906, are 95 volume per cent, 29.69 cents per gallon; 90 volume per cent, 27 cents per gallon. At wholesale the prices range from 25.2 to 26.1 cents per gallon. These are twice those of some of the previous years when crops were better. The wholesale prices of petroleum naphtha, duty paid in Berlin, for automobile use, are now 20.9 cents per gallon, for the best grade, and for a lower grade 17.7 cents per gallon.

There can be no doubt that in a progressive agricultural country like this alcohol can be produced for use in the industries more cheaply than in any other country in the world, and that its use here will soon exceed that in other countries to the same extent that many of our manufacturing industries do theirs. Our young sister republic of Cuba is selling alcohol well under 20 cents per gallon, and is using it in large quantities to run pumping stations and electric light plants, as has already been shown. If more than this is needed to indicate what can be done in an agricultural country let us recall what has been done with industrial alcohol in *this country*, but long ago forgotten. Mr. C. J. Zintheo, of the United States Department of Agriculture, states: "Special documents show that in the United States alcohol was used for lighting, cooking, and industrial purposes in the early sixties. Before 1861 the manufacture of spirits was free from all special taxes and supervision, as much on the part of the Union as on the part of the States which compose it. It resulted from this freedom that alcohol served a multitude of industrial uses. The production was enormous, amounting to ninety million gallons, coming especially from the distillation of corn. For lighting purposes enormous quantities were employed. In 1864 the city of Cincinnati alone utilized twelve thousand bushels of corn per day for distillation. Because of its low price alcohol was also used as fuel for the domestic kitchen, for bath and laundry. The establishment and successive increases of the tax on spirits had the result of upsetting all these industries and in some cases of destroying them.''

Summary of the Benefits of Industrial Alcohol to Agriculture.

It must now be clearly evident that there are many and convincing reasons why farmers and producers of alcohol generally should do everything in their power to hasten the widespread industrial use of alcohol.

The farmer's interest in this matter is twofold:

First. As a consumer, he obtains cheaper light, heat, and power.

Secondly. As a producer, he is insured of an increased and better market for his farm products and refuse.

Under these two heads the following various important facts which have been brought out in the foregoing may be summarized.

As a consumer the farmer is interested in cheap alcohol because:

1st. Coal and oil, the fuels which he will increasingly need, are now largely monopolies and their price is beyond his control.

2d. It is the belief of authorities that he will require small engines to do much of the routine labor of the farm.

3d. The demand for a liquid fuel to operate farm and other motors is increasing at a rate which will soon vastly exceed the gasolene and kerosene supply. This changing ratio of demand and supply has doubled the cost of gasolene in the past ten years, and a further advance can safely be predicted.

4th. Alcohol is well adapted to operate small motors and to do the work of coal and oil generally, as has been shown by numerous tests. Actual plowing tests demonstrate that it is about equal in efficiency to gasolene and kerosene for this purpose.

5th. Alcohol can be produced here in practically unlimited quantities, and, there is reason to believe, more cheaply than in any other country, except possibly Cuba, where it sells for less than twenty cents a gallon. It should soon, at least, cost less than gasolene.

As a producer, the farmer is interested in the progress of the industry because:

1st. The increasing insufficiency of the gasolene supply for work outside of the farm insures a vast new market for his farm products, as soon as they can be converted into alcohol and sold at a price approximately equal to that of gasolene.

2d. He can produce practically unlimited quantities of alcohol to meet this demand.

3d. It can be made from a great variety of farm products, so that every kind of soil and climate can be utilized.

4th. It can be made from spoiled crops, from refuse, corn cobs, and corn stalks, etc. From the latter alone it is estimated that one hundred million gallons of alcohol can be made yearly in this country.

5th. There is no exhaustion of the soil in producing alcohol; only carbon, hydrogen, and oxygen are withdrawn, and they come back gratuitously through the air as carbon dioxide and water. Nitrogen, phosphates, lime, etc., remain in the immediate neighborhood in the residue from alcohol manufacture, and, as will be shown, are used as fodder, and return to the ground as manure.

6th. In seasons of heavy crops and consequent low prices his farm products can be converted into alcohol and stored for any length of time in small compass and without loss until a time when poorer crops insure a better price. Alcohol is thus a sort of agricultural "balance wheel" which insures steadiness of price.

General Advice to Agriculturists.

In the light of the immense advantages just summarized of the extensive use of alcohol, the farmer cannot well fail to do everything in his power to spread its use, better the appliances for making and using the same, and help to bring its cost down to a point where it will compete at least successfully with petroleum products. He can do this in many ways, but more than all by adopting its use whenever possible and inducing others to do so. It may be taken as a certainty that every increase in demand for denatured alcohol will be met by an increased production, and that increased production will result both in increased demand for farm products yielding alcohol and in the perfecting of methods of production, with the consequent lowering of the selling price of alcohol.

In conclusion it may be well to add a few words of caution. In the first place, too much must not be expected of the alcohol industry at once; its progress is bound to be slow, and perhaps for some time hardly perceptible. There are many problems to solve which will take considerable time. Of course, we have the experience of other countries which have long made and used denatured alcohol to draw on. But it must not be forgotten that there is still much to be done, that some of our conditions are quite different, and that many of the problems are peculiarly our own.

The alcohol motor, for example, is still in its experimental stage; manufacturers in this country are now working on the problem and doubtless many engines will at once be introduced, both good and bad. But at least a season will be needed to differentiate the good from the bad and to reveal the defects which will be found even in the best. There are the same peculiar difficulties to be solved in the alcohol engine as there were in the gasolene, kerosene, and gas engines. Even these are far from perfect, and are constantly being improved, and while much of what has been done on these machines can be applied to the alcohol engine, still much more must be done before the latter is generally satisfactory. And, furthermore, it must not be expected that *any* type of internal combustion engine can be adapted to the use of alcohol with a few minor changes and give satisfactory results. This matter will be taken up later in the chapter on motors.

As regards the question of the operation of stills by the individual farmer, it must be said that it cannot be done profitably on as small a scale as it is in Germany. In the last campaign year there were over 71,000 so-called farmer distilleries in operation there, as against less than 1,000 industrial distilleries. One-fifth of the total number of distilleries produced 100 times as much alcohol as the remaining four-fifths, each one of which averaged less than 20 gallons in the year. But the government has made special provisions there which make distillation on a small scale possible. It is not required that a revenue official be present during the distillation and all subsequent operations.

The United States regulations now in force, given in the Appendix, to which the reader should refer, prescribe, however, the presence of a revenue official at each distilling plant, which must be registered and bonded; and the erection of buildings of a certain form of construction, fitted up with special appliances for the denaturing process (Sections 2 to 4), which also must be registered and bonded (Sections 10, 11). Not less than 300 wine gallons of alcohol may be withdrawn from bond at a time for denaturing (Section 15), and a revenue official must always be present during the removal (Section 20) and the denaturing process (Section 31).

Under the present regulations, therefore, small-scale operation is out of the question, and the farmer is earnestly advised not to think of attempting it. In time, perhaps, provisions may be made which will make small-scale distillation a possibility. But before deciding to embark on the production of alcohol the farmer must remember that with larger and more costly apparatus better yields can be obtained, as well as more valuable by-products, and that the cost is greatly reduced thereby. He can afford to produce alcohol himself only when he can do so cheaper than he can buy it. This he will be able to do, perhaps, only from farm products which have little or no market value. And even these it will be best to work up on a co-operative basis with his neighbors. A central co-operative distillery using all such farm products within a radius of ten miles or so can doubtless compete successfully with any distant very large-scale plant because there will be considerable saving in transportation costs, both of the raw products and of the spirit produced, provided the latter is used near by. The keynote to success for the small farmer, therefore, lies in intelligent and harmonious co-operation in production and in the extensive use of denatured alcohol on the farm and in the home.

DISTILLATION.

A SUMMARY OF THE PROCESSES IN SPIRIT MANUFACTURE.

1. Certain farinaceous materials are suited to the manufacture of spirit in the distillery; these comprise, primarily, potatoes and the farinaceous grains of the cereals.

2. Only certain varieties of sugar are capable of yielding alcohol through fermentation, and therefore it is first necessary to convert the starch into a sugar which is capable of producing alcohol fermentatively.

3. This change is effected by allowing malt (germinated grain) to act upon the starch of the raw material. The malt contains curious nitrogenous bodies known as "enzymes," among which is "diastase." The latter possesses the property, under certain conditions, of converting starch into a series of simpler substances (dextrins) and finally into sugar (maltose). The malt for this purpose is generally prepared from barley, and, less frequently, from oats or rye.

4. It is possible, also, to convert the starch into sugar by heating it with acids. The sugar obtained as final product in this process is "dextrose," which can be fermented directly.

5. Before the malt can act upon the starch it is necessary to gelatinize the latter, that is, to convert it into a paste by heating with water, or better, change it into a liquid condition by steaming under high pressure. This transformation is effected in special high-pressure apparatus. Of this type the Henze apparatus is most widely employed.

6. The raw materials, softened and disintegrated, and

placed in the preparatory mash vat, are "saccharified," after they have been cooled to the mashing temperature, by the addition of malt; that is, the starch therein is converted into sugar.

7. After cooling to a low temperature, the yeast, a substance which induces the initial fermentation, is added, and by means of this the alcohol is produced from the sugar. Yeast is a mono-cellular organism, a fungus, which inhabits the mash and utilizes the sugar in the processes of its life changes.

8. Yeast is cultivated from a bed of mother yeast in a yeast mash. This must contain all the substances necessary for the nutrition and reproduction of the yeast, and must, furthermore, be so conducted that, if possible, the yeast alone is developed without the simultaneous production of micro-organisms inimical to fermentation. Yeast production is to-day carried out almost universally in accordance with the laws of the "natural pure culture" formulated by Delbrück. The expert in fermentation is able to regulate the battle for supremacy between the fungi so that it leads to the destruction of harmful organisms and to the survival of the desired culture yeast.

9. When the yeast has ripened it is placed with the sweet mash in the fermenting tub, or where water-cooled preparatory mash vats are available, directly in these and afterward, together with the mash, in the fermenting vat. At the proper temperature it induces fermentation so that the sugar is split up into alcohol, which remains in the mash, and carbonic acid, which escapes. At this stage of the process it is necessary to maintain the temperature within certain limits in order to obtain the highest possible alcohol production from the mashed raw material.

10. As the alcohol produced in the fermented mash is volatile in nature, it can be converted into vapor by heating in proper apparatus, and can be strengthened in

special devices which to-day are included directly in all distilling apparatus. It is then condensed to high-percentage spirit (raw spirit) in coolers.

11. As this raw spirit still contains fusel oils and other by-product constituents of unpleasant taste and odor, it must undergo a purifying process, filtration and rectification, before being available for the best uses. The purification is usually accomplished in special apparatus in alcohol refineries. Within the past few years, however, distilling apparatus which produces clean or rectified spirit directly from the mash has been designed and successfully utilized.

12. The mash when freed from spirit is called residual liquid or spent wash, and provides a useful fodder for agricultural domestic animals. It has been found advantageous to feed it to cattle while it is still moist and warm. However, it is often worked into a dry state in special drying apparatus, and is used in the form of cakes.

13. It is also possible to produce alcohol from certain saccharriferous substances such as grapes, figs, sugar beets, and the residual molasses from sugar manufacture. As these substances already contain sugar, the reader will understand that they do not need to undergo the mashing process necessary with starchy raw materials, and it is therefore possible to ferment them directly with yeast, after sufficient comminution. Consequently, the manufacture of alcohol from materials of this nature is simpler than that from starchy substances.

Within recent years serious attempts have been made to produce spirit from substances, especially wood and peat, in which fermentable sugar can be obtained through the conversion of cellulose. The results of the experiments and tests which have been made so far are not promising, and it would appear that the prospect for the lucrative production of alcohol by this method is slight.

PART I.

STARCH, HOW IT IS FORMED, ITS CHARACTERISTICS, AND THE CHANGES IT UNDERGOES IN SPIRIT MANUFACTURE.

I.—The Forms of Starch.

STARCH is the first assimilative product of the chlorophyllaceous plant cell. It is a soft, white powder, glistening in sunlight, and it consists of granules varying widely in size and possessing a distinct form for each of the various starchy substances. Thus, the starch of potatoes, Fig. 1, consists of oval granules, lentil-shaped in cross section and having, in many cases, evenly crimped edges. Each granule has an eccentrically-located kernel or nucleus, usually near the smaller end of the granule. The similarly eccentric layers or strata are numerous and generally distinctly marked; some of these are always clearly visible under the microscope. Besides these oval granules there are smaller circular ones which, perhaps, should be regarded as undeveloped forms of the others.

The starch granules of rye, wheat, and barley are quite different from those of the potato, but resemble one another rather closely, so that while they can be differentiated only by means of careful microscopic measurements, they are easily distinguished from those of all other varieties of starch. They always comprise granules of two distinct sizes, with no transitional forms of intermediate size. The large granules are lentil-shaped, the smaller ones spherical, though sometimes of polygonal form. They are usually unstratified or show but few layers, and the nucleus is seldom apparent, though its location may be indicated by one or more fissures in the granule. The smaller granules are always unstratified, as shown in Fig. 2.

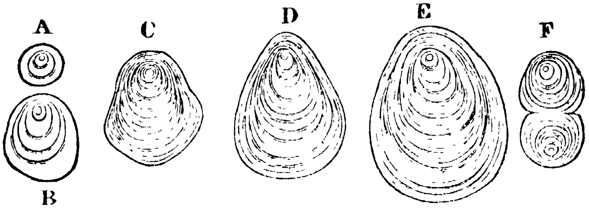

Fig. 1.—Potato Starch Magnified 300 Diameters.

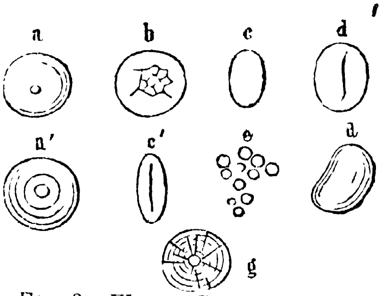

Fig. 2.—Wheat Starch Magnified 300 Diameters.

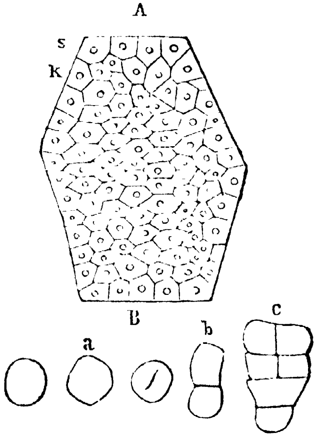

Fig. 3—Corn Starch Magnified 300 Diameters.

Maize or corn starch consists mainly of aggregated granules containing many simple granules of round, spherical, or polygonal form. Some simple granules are found in the inner, farinaceous part of the maize grain, while in the outer, horny part, on the other hand, the starch granules lie closely pressed together and compacted into unnatural forms. Fig. 3 shows simple and aggregated corn starch granules.

According to Wiesner the average sizes of corn starch granules are as follows:

	Millimeter.
Barley (large granules)	0.0203
Wheat (large granules)	0.0282
Rye (large granules)	0.0369
Potatoes (large granules)	0.070
Oats (aggregated granules)	0.031
Corn (aggregated granules)	0.047

Of the different kinds of starch used in alcohol manufacture, that of the potato presents by far the largest granules. Starch granules appear to possess a resistant envelope that is, perhaps, cellulose. According to Nageli starch is an intimate mixture of two isomeric bodies, starch granulose and starch cellulose.

II.—The Composition and Formation of Starch.

Starch or amylum is a carbohydrate. The carbohydrates comprise a class of bodies which are widely distributed throughout the vegetable kingdom and which form the most important constituent of plant life. They belong to the hexane series and are divided into three groups. The third of these comprises dextrin, gum, glycogen, starch, cellulose, tunicine, and mucilage, and it possesses the formula $C_6H_{10}O_5$. Of these constituents C represents 44.44 per cent, H 6.17, and O 49.39. The above formula, however, does not express the molecular size of the starch granule; starch must rather be regarded as a polysaccharide, in which numerous groups having the composition $C_6H_{10}O_5$ have combined to form a large, complex, molecular body of involved stratification.

Starch is formed in the green portions of plants through the combination of carbonic acid and water by means of a reduction process expressed by the formula

$$\underset{\text{Carbonic Acid}}{6CO_2} + \underset{\text{Water}}{5H_2O} = \underset{\text{Starch}}{C_6H_{10}O_5} + \underset{\text{Oxygen}}{12O}.$$

The process of starch formation is dependent upon, or at least influenced by, the action of the luminous rays of the sun. The starch formed in the green cells is freed by enzymes and is then converted into sugar. The sugar, in solution, is distributed throughout the plant and is stored at certain points, such as the grains or tubercles, after it has again been converted into starch. The physiological purpose of this storing up of starch is to provide formative and nutritive elements for the propagation of new vegetable life.

III.—The Characteristics of Starch.

The specific gravity of dry starch varies between 1.5029 (air dry) and 1.653 (completely dry). It distorts the plane of polarization sharply to the right $(\alpha_j = +219.5)$. It is a strongly hygroscopic substance. That is, when it has been thoroughly dried at a high temperature, starch will absorb considerable quantities of water from moisture-laden air. The quantities of absorbed moisture, however, vary with the kind of starch in question. The most strongly hygroscopic of the starches is that of the potato. Starch is completely soluble in alcohol and ether, as well as in other commonly employed solvents.

The Behavior of Starch Relative to Water.—Ungelatinized starch is not affected by cold water. In hot water the process ordinarily known as gelatinization or impasting takes place. With rising temperature of the water the starch absorbs increasing quantities of moisture. At the beginning of the gelatinization the starch granules begin to crack near the nucleus, the cracks extending in the direction of the thinnest layers; at 129° F. some of the grains swell and burst; many more undergo the same change at 138° to 140°, at 142° still more, and at 144° to 147° nearly all of the granules burst, while between 149° and 176° the real gelatinization takes place in the majority of the starches, that is, the transformation into the well-known glue-like opalescent mass. The final temperature of the gelatinizing process varies with the different starches as follows:

Potato starch	149° F.
Barley starch	176° F
Oat starch	185° F.
Rye starch	176° F.
Wheat starch	176° F.
Corn starch	167° F.

The temperatures of gelatinization according to Lippmann are as follows:

Variety of Starch.	Distinct Swelling. Degrees F	Commencement of Gelatinization, Degrees F.	Complete Gelatinization, Degrees F.
Rye starch	113.00	122.00	131.00
Corn starch	122.00	131.00	144.50
Horse chestnut starch	126.50	133.25	137.75
Barley starch	99.50	135.50	144.50
Chestnut starch	126.50	137.75	144.50
Potato starch	115.25	137.75	144.50
Rice starch	128.75	137.75	142.25
Wheat starch	122.00	149.00	153.50
Buckwheat starch	131.00	155.75	160.25

It is to be noted that cereal starch requires a temperature for the commencement of gelatinization higher by 59° F. than that necessary for potato starch, notwithstanding that the granules of cereal starch, with the exception of corn and rice, dissolve more readily in the presence of malt than do those of potato starch. A certain quantity of water is requisite for gelatinization; Saare has determined this quantity to be 0.4 part by weight of water for each part of air-dried starch. However, greater quantities of water are necessary for rapid and complete paste formation. By the action of cold water malt extract is transformed into dextrin and maltose.

O'Sullivan has shown that the variety of sugar formed by the action of diastase upon starch is maltose and not glucose. The chemical process of transformation is in accordance with the formula

$$\underset{\text{Starch}}{C_{18}H_{30}O_{15}} + \underset{\text{Water}}{H_2O} = \underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + \underset{\text{Dextrin}}{C_6H_{10}O_5}$$

From 100 parts of starch are obtained 67.85 parts of maltose and 32.15 of dextrin. Recent investigations have demonstrated conclusively that the proportionate quantities of maltose and dextrin depend upon the process of mashing and, especially, upon the temperature during that operation. Thus the above equation is admissible only for a temperature of about 145° F.; the resulting quantities of maltose and dextrin vary widely from the figures given, with different temperatures. Thus, if the mashing temperature is raised above 158° F., 100 parts of starch yield 17.4 of maltose and 82.6 of dextrin.

Behavior of Starch Under High Pressure.—When starch is properly mixed with water, preferably in the proportions of 1 to 4, and is heated in a closed vessel, gelatinization occurs rapidly; if the temperature in the vessel rises to about 230° F., the thick, viscous paste begins to melt, and between 248° and 270° F. it becomes completely fluid. It can afterward be cooled to 122° F. without immediate regelatinization. The latter action does not occur until after the solution has stood for a considerable period. This fact is of the greatest importance in the practice of distillation. The starchy raw materials are steamed under high pressure, and thus the starch is obtained in a solution which remains at least partially fluid after being cooled to the mashing temperature. In this solution the conversion of the starch into sugar is effected completely and almost instantaneously by the malt. For this reason sugar formation takes place with much greater rapidity when the raw materials are prepared under pressure than when the starch is gelatinized by cooking alone. Furthermore, as the disintegration is more complete in the first method of operation, the quantities of sugar and alcohol obtained are correspondingly greater than when the second method is used.

IV.—*Starch* Reactions.

The term dextrin is more general than special, for starch is converted into several dextrins by the action of mineral acids, particularly hydrochloric acid, as well as by organic acids, such as oxalic acid. By the continued action of the acids the starch is further changed into dextrose. By the action of these acids or of concentrated alkalies, starch first forms a subsidiary variety, which is soluble in water and is known as soluble starch or amylo-dextrin; this remains soluble for a considerable time, even after it has been freed from the acid or the alkali which effected the conversion, and it is only very gradually reconverted into the insoluble modification. Soluble starch can be produced as follows: 3 parts of starch are ground up with 2 parts of concentrated sulphuric acid, and the white, translucent mass is then triturated with alcohol after being allowed to stand for half an hour, and is finally washed with alcohol until the acid reaction disappears. In Lintner's method the starch is allowed to stand in a 7.5 per cent solution of hydrochloric acid for six or eight days at ordinary temperature, is washed repeatedly with water till the acid reaction disappears, and is then dried in air. The product called erythro-dextrin may be classed with the achroo-dextrins which give no reaction with iodine. Soluble starch evidences all the reactions shown by ordinary starch. Neither soluble nor insoluble starch will reduce Fehling's alkaline copper solution, whereas certain varieties of sugar decompose this solution with the separation of red copper protoxide.

With concentrated alkalies, not however with ammonia, starch swells and forms gelatinous combinations; baryta, strontium, and lime give similar combinations which are absolutely insoluble in water. Gelatinized, as well as soluble starch, is precipitated by tannic acid. One of the most important reactions of starch is that in the presence of tincture of iodine, or of an iodine solution in iodide of potassium. Insoluble, gelatinized, and even soluble starch are colored an intense blue by the iodine solution which forms iodine starch. This reaction is so clear and distinctive that it is possible to demonstrate by means of it the presence of even the minutest quantities of starch. The solution to be used in the test for starch is best prepared by adding to 1 liter of water 5 grammes of iodine ground up with 10 grammes of iodide of potassium and a little water and then diluted to 1 liter. Old iodine solution which has stood for some time and in which appreciable hydriodic acid has been formed, gives an incomplete reaction; it is therefore advisable to prepare a new solution for use in the distillery at least once every three years.

In using the iodine reaction for the determination of starch, certain rules should be observed. The liquid which is to be tested should not be hot, as iodine combines with starch to manifest the blue reaction only at low temperatures. If, for instance, a solution which has been colored blue by iodine is heated to 140° or 160° F. the discoloration disappears. The blue color reappears if the iodine is liberated by the addition of potassium nitrite and a drop of sulphuric acid. If iodine starch be heated for a long time a permanent discoloration takes place, as the application of the heat has changed the iodine to hydriodic acid. The presence of caustic alkalies, alkaline carbonates, and alkaline earths, such as lime and baryta, disturbs the iodine reaction, as these substances themselves react with iodine. The presence of sulphureted hydrogen or sulphuric acid similarly interferes with the reaction.

It sometimes happens that the mash contains substances which decompose the iodine solution with the formation of hydriodic acid, so that under certain circumstances there is no apparent reaction when but a few drops of the solution are added to the starch fluid. Consequently, it is always necessary to use a considerable quantity of the solution to insure the reaction with starch, though care should be taken not to add too much, as a very large quantity of the iodine solution influences the resulting color. Starch takes up iodine from other substances discolored through the action of iodine, as for instance albuminoids. In a mixture of such substances the discoloration of the albuminoids does not occur until the iodine absorption by the starch is completed, that is, until the starch is saturated. A sufficient addition of iodine is, therefore, also necessary for the success of the reaction in this case.

V.—The Behavior of Starch with Respect to Acids and Diastase.

By treating starch with dilute acids it is first converted into soluble starch, then into dextrin, maltose, and finally into dextrose (grape sugar) which is capable of direct fermentation.

In the fermentation industries, the utilization of the starch is made possible through the enzymes, especially the diastase contained in malt. By the action of the diastase the starch is first dissolved, and is then changed successively into a series of intermediate products (dextrins) and then into a variety of fermentable sugar (maltose) which is split up and is subsequently fermented by means of an enzyme (maltase) found in yeast and related to diastase. These fundamental processes are of the utmost importance in distillation and will be discussed later at greater length.

PART II.

THE ENZYMES OR FERMENTS.

I.—GENERAL INTRODUCTION.

THE most important processes in the fermentation industries depend upon the action of enzymes or ferments. Under the term ferments is understood a series of organic substances, which when added in small quantities to other organic bodies are capable of decomposing the latter without resulting change in themselves. In general, ferments may be classed as *unorganized* or *chemical ferments* (enzymes) and *organized* or *vegetable ferments*. The enzymes, with respect to their properties, are similar to the peptones; they are nitrogenous proteins, albuminous bodies which are impossible of coagulation. The enzymes lose their decompositive efficacy at temperatures of 194° F. and over—most of them, however, at 212° F. They can more easily resist a dry heat than a moist one, and thus diastase in a dry state can withstand a temperature of from 248° to 257° F. without losing its efficacy. Diastase is classed with the unorganized ferments, while yeast is generally recognized as belonging to the vegetable or organized ferments. According to recent investigations, however, its efficacy is also caused by a chemical ferment.

Up to the present time it has been impossible to isolate and produce enzymes in the pure state, but their effects and properties are sufficient to characterize them. Thus, the latter demonstrate that the enzymes closely resemble albuminoids, even in their chemical compositions, and that they strongly affect other combinations to bring about the decomposition of the latter and to convert them into simpler bodies without being themselves altered by these processes. This is called the decompositive efficacy of the enzymes, and it explains the phenomenon that very small masses of the ferments are capable of decomposing large quantities of the substances acted upon. Usually the action appears to continue until a condition of equilibrium has been established between the substance to be decomposed and the separated products. If there is more of the latter present than corresponds to the condition of equilibrium, the enzymes must, according to the laws of chemical balance, effect the building up of the original substance from the separated products until the balance is re-established. This is called the formative efficacy of the enzymes. The "reversions" observed in experimental investigations would appear to confirm this theory.

II.- CLASSIFICATION OF THE ENZYMES ACCORDING TO THEIR ACTIONS.

1.—Carbohydrate Enzymes.

These enzymes effect the decomposition of carbohydrates of complex molecular constitution into simpler carbohydrates. They include:

A. *Diastase*, which decomposes starch. The resulting products are dextrin, maltodextrin, and maltose.

B. *Maltase;* this splits up maltose into the directly fermentable dextrose. The related enzyme *glucase* is capable of decomposing starch into dextrose.

C. *Invertase* converts cane sugar into inverted sugar, a mixture of dextrose and levulose.

2.—Proteolytic Enzymes.

These are able to decompose albumens. They are characterized according to the final products of the decomposition as (*a*) peptic, with which the final products are peptones, and (*b*) tryptic, with which the decomposition products are amides; to these belong the *peptase* of malt and the *endotrypsin* (*peptase*) of yeast.

3.—Zymase.

This is an enzyme of yeast which during fermentation separates sugar into alcohol and carbonic acid.

4.—The Oxydases.

These are enzymes which effect oxidation processes, and which are of great importance in the production of the necessary living energy of the cell by the combustion of the nutritive substances. In this action sugar is consumed to water and carbonic acid through the taking up of oxygen.

5. Lipases.

The activity of these enzymes consists in the decomposition of the fats. To their efficacy can probably be ascribed the appearance of glycerine during fermentation.

III.-THE ENZYMES OF GREATEST IMPORTANCE IN THE DISTILLATION PROCESSES.

Certain of the enzymes are of great importance in connection with the processes of the distillation industry, and these require special consideration.

1.—Diastase.

Diastase is the enzyme of malt which effects the conversion of starch into soluble starch, dextrin, and finally maltose. It is formed in the processes of germination, either artificial or natural, and increases with the duration of the growth of the grains. The sugar-forming enzyme of the ungerminated grains differs from diastase. The latter is found in the vegetative parts of the organisms, and is largely influential in the transfer and distribution of the carbohydrates in the green plant. This is called the translocation diastase. The first, known as the secretion diastase, appears to be confined to germinating seed. The diastases differ markedly in their effects upon gelatinized as well as ungelatinized starch. The first dissolves the starch without initial corrosion, the most favorable temperature for this action lying between 113° and 122° F.; the latter, on the other hand, first destroys the form of the starch granules and then dissolves the corroded starch, the best temperature for the action of this diastase being from 122° to 131° F. This temperature is of importance in connection with the regulation of the mashing temperature. At both higher and lower temperatures the action of the diastase is retarded. The temperature maximum for the action approximates 185° F. At this degree of heat diastase can only liquefy the starch and can effect no further change in it. In concentrated mashes rich in sugar it is less sensitive to higher temperatures than in poorer mashes. At favorable temperature and with long periods of activity, very small masses of the enzyme are capable of converting unproportionately large quantities of starch into sugar; in practice, however, it is customary to use larger masses of the enzyme, in order to complete the action as rapidly as possible.

Diastase is soluble in water. According to Osborne, it possesses the following chemical composition:

	Per cent.
Carbon	52.50
Hydrogen	6.72
Nitrogen	16.10
Sulphur	1.90
Oxygen	22.78

These figures correspond substantially to those representing the composition of an albumen. In its other characteristics, too, there is an apparent similarity to those of the albumens. Thus substances which coagulate albuminoids or form insoluble combinations therewith, similarly affect diastase. This accounts for the discoloration and the precipitation of flakes in cooking the watery solution. Similarly, diastase in solution is coagulated and rendered ineffective through the action of certain acids, especially the lactic, butyric, and acetic acids present in the mashes, and, less readily, by the salts of the heavy metals.

Certain substances have an irritating and stimulating effect upon diastase; among these are asparagin, particularly in the presence of carbonic acid, small quantities of mineral acids, especially hydrofluoric acid and its salts, as well as small quantities of certain phosphates. Lactic acid *in small quantities* also has a favorable effect upon the action of diastase.

2.—Peptase.

Besides the decomposition of starch which is effected by diastase, the decomposition of albuminoids is of importance in alcohol and yeast manufacture. The purpose of the albumen contained in the raw vegetable matter is, in general, to provide nutriment for the growing germ or seed, or to act as the basic substance for the formation of enzymes, but it is adapted for this purpose only when it has been made diffusible. The albumen is rendered diffusible by the peptase, and thus the latter plays an important role in the preparation of the malt and in the nourishing of the yeast. Malt peptase is present in ungerminated barley in very minute quantities only, but during the germinating process these increase substantially. The enzyme acts upon the albumen of the grain in different degrees, according to the temperature and the quantities of acid present in the solution. At a low temperature the decomposition is slow but widespread, while at higher temperatures it is more rapid but less comprehensive. Small quantities of organic acid have a favorable effect with regard to the masses of the decomposed albumen. The final products of the decomposition are substances which resemble the amides. According to **Windisch** and Schellhorn, the enzyme in solution can withstand temperatures up to 140° F. and is destroyed at 158° F.

Among the albumen-decomposing enzymes, yeast peptase (endotrypsin) is of great importance. It introduces albumen into the yeast and provides nutriment for it. It becomes active as a feeding enzyme, not only when the yeast receives nourishment from external sources, but also when nutriment from an outside supply is not available. In the latter case it renders the reserve albumen digestible and capable of utilization by the yeast. The development may even go so far that the peptase attacks the protoplasm itself of the cell, and thereby causes the destruction of the yeast. The action of the enzyme upon the yeast is apparent in the changes which it effects in the characteristics of the same. Floccular yeasts become powdery. Yeasts of consistent or solid form become soft, according to Lange. The activity of the enzyme is increased by raising the temperature. This characteristic is utilized in practice in the treatment of surface yeast, in yeast culture, and in artificial yeast preparation. The peptase regulates and governs the well-being of the yeast cell. It is very closely related to the sugar-decomposing enzyme, zymase.

3.—Zymase.

According to the entirely new viewpoint presented by C. Buchner after his recent investigations, zymase is the enzyme of the yeast which effects alcoholic fermentation. It was discovered by Buchner in 1896, when he produced a cell-free compressed yeast liquor, which set up fermentation in a sugar solution. As the sugar was split up quantitatively into alcohol and carbonic acid, it was proven by these researches of Buchner that alcoholic fermentation is an enzymotic process. If mixed with an equal volume of cane sugar solution, expressed yeast liquor sets up a regular evolution of carbonic acid, within one-quarter to one hour, which continues for days. Solutions of other varieties of sugar behave in a similar manner, but no phenomena of fermentation appear in solutions of milk sugar and mannite. The characteristics of the enzyme have been closely studied by means of the expressed yeast liquor. The enzyme is very sensitive to higher temperatures. When separated from the cell it soon becomes in active, even at the ordinary temperature of the room. Cooling by means of ice or other refrigeration is therefore employed in its preparation. In the cell itself it is capable of withstanding temperatures considerably higher than in the expressed liquor. Even under gradual withdrawal of moisture from the yeast in a vacuum, together with the application of heat (233° F.) for several hours in a current of hydrogen, the enzyme, according to Buchner, still retains its fermentative efficacy. In a sugar solution, even at a warm temperature, it remains active for a considerable period. In highly concentrated sugar solutions the fermentative power is unproportionately stronger than in dilute solutions.

When expressed yeast liquor is allowed to stand for some time, an albuminous turbidity soon manifests itself without the appearance, however, of microscopic organisms. Its fermenting power is not destroyed by filtering through diatomaceous earth, which retains the yeast cells present in solution. If a tube of parchment paper be suspended in a 37 per cent solution of cane sugar, the surface of the tube becomes covered with innumerable minute bubbles of gas within a few hours, while a strong evolution of gas is evident in the interior of the tube. It would seem that the enzyme loses its fermentative efficacy, either partially or entirely, when precipitated with alcohol.

The zymase enzyme finds protection against the peptase enzyme in the sugar. The antagonism between the two enzymes is less evident when the cell is sufficiently nourished, and it is only very active when the cell is in a starved condition, for instance, when the solution is at rest. The temperature especially is an important factor in this connection. According to the storage temperature, low or high, the one or the other enzyme obtains the mastery. Stored at a temperature of 34° to 36° F., the zymase of the yeast increases for a considerable period; at 77° to 86° F. it is usually destroyed even after but a few days (Delbrück, Lange, and Haymann). Peptase is favored in its development by warmer temperatures. Stored yeast becomes soft in standing, its fermentative efficacy being destroyed, as it were, in the yeast itself. Fermentation will be normally induced when it is possible to conduct the development of the enzyme in such a manner that the zymase retains its mastery over the peptase.

While it appears that the active agent in the liquid is a nitrogenous compound of enzymotic nature which decomposes sugar in accordance with the enzyme theory of Traube and Hoppe-Seiler, it is not yet quite clear how this decomposition is effected. While invertin can be readily extracted with water from destroyed yeast cells, active zymase has not up to the present been obtained in this manner. Zymase appears to be a constituent of the living plasma, similar to the inverting ferment of *Monilia candida,* and not a constant soluble enzyme. The fermentation of the sugar may take place inside the yeast cell, though more probably the albuminous body is separated by the yeast cell during the fermentation in the sugar solution. According to Buchner, the fermenting process is, therefore, a physiological one in so far only as the zymase is separated by the living yeast cells. The expressed liquor from grain yeast probably contains a peptic enzyme which has rendered the zymase ineffective; the living residues of the plasma of the yeast cells do not induce fermentation, as the fermentative effect is not destroyed by chloroform, benzol, or by other antiseptics. Vigorous fermentation has been set up with pure uninjured yeast carefully dried in air and heated to 212° F., though yeast heated to from 284° to 293° F. was destroyed at these temperatures.

PART III.

THE PRODUCTS OF FERMENTATION.

IN pure fermentation sugar, $C_6H_{12}O_6$, is theoretically split up into alcohol and carbonic acid, according to the formula:

$$\underset{\text{Sugar}}{C_6H_{12}O_6} = \underset{\text{Carbonic acid}}{2CO_2} + \underset{\text{Ethyl alcohol}}{2C_2H_6O}.$$

But the decomposition of sugar by means of the yeast is not as smooth a process as this, for there is always formed a number of by-products which decrease the amount of alcohol recovered. The quantity of these by-products may be regarded as representing from 4 to 6 per cent of the sugar.

I.—Alcohol (Spirit of Wine).

The chief product of fermentation is ethyl alcohol or spirit of wine; 100 parts of sugar (dextrose) would yield 51.14 parts of alcohol and 48.86 parts of carbonic acid by absolute decomposition. However, in practice, as said before, the alcohol yield is never as high as this, for a certain proportion of the sugar is otherwise acted upon by the yeast, and is converted into other substances by fermentation. Pure anhydrous alcohol, "absolute" alcohol, consists of carbon 52.12 per cent, hydrogen 13.14 per cent, and oxygen 34.74 per cent. Its constitution in atomic weights is $C_2 = 24$, $H_6 = 6$, and $O = 16$.

Spirit belongs to the group of homologous bodies to which the generic term of alcohol is applied. The first in this series is methyl, or wood alcohol. The next, the alcohol here in question, is ethyl alcohol. Then follow in order, propyl alcohol, butyl alcohol, etc. By oxidation these alcohols are converted into the corresponding acids as, for instance, formic acid from methyl alcohol, acetic acid from ethyl alcohol, propionic acid from propyl alcohol, etc.

Ethyl alcohol is a thin, mobile, inflammable, and strongly refractive liquid without specific taste or odor, and it can be mixed with water in any desired proportion. In mixing alcohol with water a contraction takes place, so that 50 parts of alcohol mingled with 50 parts of water yield, not 100, but 96.4 parts of diluted alcohol. In consequence of this contraction, heat is evolved during the mingling of the alcohol and the water. Absolute alcohol possesses strong attraction for water, and retains it tenaciously in solution. The specific weight of absolute alcohol at 15° C. or 59° F. is 0.794, and its boiling point is 78.4° C. or 173° F.

As the boiling point of water is 100° C. or 212° F. the determination of the boiling point of an alcoholic fluid affords a means for ascertaining the quantity of alcohol contained in it. Furthermore, between its freezing point and its boiling point, alcohol expands 0.0936 of its volume, while the co-efficient of expansion of water between the same degrees is 0.0278; the expansion of alcohol is thus 3 1/3 times greater than that of water. This fact is made the basis of a method of alcoholometry in which the variation in height of a column of mercury subjected to the pressure of alcohol vapor and of water vapor is made a measure of the quantity of alcohol contained in a fluid, the differences in the tensions being observable. If alcohol be mixed with snow in the proportion of 2 to 1, the temperature of the mixture falls to —5.8° F.

Mixtures of alcohol and water have higher specific gravities than absolute alcohol, and a definite specific gravity corresponds to each mixture, so that it is possible to determine the proportionate alcohol content of each mixture by ascertaining the specific gravity of the same. This is determined in practice by means of an alcoholometer.

As alcohol is volatile and vaporizes in boiling, it can be driven from the mash by distillation; the non-volatile constituents—unfermented sugar, spent malt, husks, yeasts, salts, and the non-volatile by-products of the fermentation—remain with the greater part of the water as "wash." As alcohol is more volatile than water, a stronger alcohol distills over from a mixture of alcohol and water in the mash than is contained therein; therefore, if the distillation be repeated a number of times, it is possible to strengthen the alcohol up to a certain limit—about 97 per cent. This was the process of the old distilleries, and it was carried out with simple apparatus. Here the distillation was repeated until the desired strength of the alcohol was attained, though this method of producing high percentage spirit was expensive and slow. In modern distilling apparatus the alcohol is produced highly concentrated by a single operation, comprising, however, numerous and repeated concentrations and redistillations. The remaining 3 to 4 per cent of water in the spirit cannot be removed even by the best and most highly improved apparatus. To accomplish this final removal and to obtain absolutely pure spirit, it is necessary to employ chemical substances capable of absorbing water, such as quicklime, fused calcium chloride, metallic sodium, barium oxide, or dehydrated sulphate of copper.

Alcohol freezes at extremely low temperatures only; it congeals to a crystalline mass which melts at —112° C. or —169.6° F. Thus it is well suited for use in thermometers adapted for the determination of great degrees of cold. It is of great value as a solvent for many substances, including resins, volatile oils, ethers, fatty acids, and numerous salts. When ignited it burns to carbonic acid and water with the evolution of considerable heat, but with a flame only slightly luminous and without giving off soot. The heating value of absolute alcohol lies between 13,310 B.T.U. and 11,664 B.T.U.; its utilization for technical purposes in motors, illuminating devices, etc., is due to its high heating value. Absolute alcohol is an active poison; moderately taken in a dilute condition it is adapted to replace sugar as a nutritive substance, and has a stimulant effect, at least temporarily, upon the human system.

II.—Carbonic Acid (Carbon Dioxide).

In fermentation the product of greatest importance after alcohol is carbonic acid, a gas of peculiar, weakly acid taste, heavier than atmospheric air, and with a specific gravity of 1,833 at a temperature of 59° F. and a pressure of 760 millimeters (29.9 inches); 1 cubic foot of carbonic acid weighs 1.95 ounces. Because of its high specific gravity carbonic acid is apt to gather in the lower portions of fermenting houses, and if the ventilation in these is insufficient, is liable to affect animal organisms poisonously. It does not support combustion and is, in fact, capable of extinguishing burning material. It is possible to detect dangerous quantities of carbonic acid in fermenting houses by the behavior of lamps and other lights, which are put out by the gas.

III.—The By-Products of Fermentation.

The by-products of fermentation are fusel oils (primarily amyl alcohol, $C_5H_{12}O$) as well as several isomeric and homologous alcohols and their ethers. The fusel oils are mixtures of alcohols boiling at higher temperatures than ethyl alcohol, and their compositions vary with the raw materials used in the production of the alcohol. Thus, for instance, wine fusel oil contains normal propyl alcohol, C_3H_8O, while normal butyl alcohol, $C_4H_{10}O$, arises from the glycerine formed during fermentation in the presence of calcium carbonate. Fusel oil, amyl alcohol being especially understood under this generic name, is produced not only through the fermentation effected by alcoholic yeast, but also by bacterial fermentation. Although the formation of fusel oil is not yet thoroughly understood, it may nevertheless be assumed that a pure, well-nourished, and active yeast produces less fusel oil than a weaker one, and that less of the substance appears at the beginning than near the end of the action. There are also ether-forming yeasts. The kind and number of the by-products depend upon the variety of the yeast used.

In addition to the fusel oils, succinic acid and glycerine are regular by products, constituting together about 4 per cent of the decomposed sugar. The theories concerning their production were, until lately, rather vague. After Buchner, however, had proven that these by-products appeared even in non-cellular fermentation, there could be little doubt that enzymotic action gave rise to them. Perhaps the formation of glycerine can be attributed to a lipase, and that of succinic acid to an oxydase.

The aldehyde and acetic acid which are sometimes present in the mash could also be formed by the yeast, but they are usually due to secondary decompositions of the alcohol already formed. The presence of these substances is, therefore, detrimental to the alcohol production. Aldehyde is a colorless, very mobile liquid with a suffocating odor, and is formed by the oxidation of ethyl alcohol. It is found chiefly in alcohol obtained from sugar beets, and at higher temperatures is miscible with alcohol and water, and is soluble in ether in all proportions. It is readily combustible and has a specific gravity of 0.8. By further oxidation of the alcohol, acetic acid is formed. This may also be obtained in the destructive distillation of wood, from the watery fluid or wood-tar liquor produced.

PART IV.

FARINACEOUS RAW MATERIALS IN SPIRIT MANUFACTURE.

I.—THE POTATO.

1.—The Composition and Qualities of Potatoes.

THE potato (*Solanum tuberosum*) was originally found in Chili, Peru, and Mexico; it was introduced into Europe in the sixteenth century, though at first only as a luxury. Since the beginning of the eighteenth century, it has become an important and popular article of food; but it was not used in the industry of distillation until the latter part of the same century. It is remarkably well adapted for this purpose as, with the exception of water, starch is its main constituent.

The yield of potatoes, as well as the quantity of starch contained in them, depends largely on the soil in which they are grown and on the meteorological conditions during their growth. Clayey sand, or sandy clay, in dry, elevated localities seems best adapted to profitable potato culture. Over one thousand varieties of potatoes are at present known; these are divided into early and late potatoes, according to the season of the year in which they ripen. Certain kinds thrive best under definite climatic and soil conditions, and it is largely a matter of trial to ascertain the variety best suited to a particular locality. Within recent years potatoes have been greatly improved, and experiments to produce vigorous potatoes from seed have met with fair success, the varieties produced showing not only great power of resisting disease, but being also distinguished by a high percentage of starch.

The average composition of a potato available for distilling purposes is:

Water	75.48
Dry substances	24.52
Nitrogenous substances	1.95
Fat	0.15
Starch	16.00—24.00
Non-nitrogenous extractive substances	2.69
Woody fibers	0.75
Ash	0.98

Starch, the fermentable, sugar-yielding carbohydrate, is the most important constituent of the potato for the distilling processes. Not only is the expense of raising a large crop of potatoes, poor in starch, higher than the corresponding cost for the production of a smaller crop of the tubers having a higher starch content, but, furthermore, the expense of working the former is higher than that necessary to produce an equal quantity of alcohol from the latter. Finally, it is possible to utilize the bonded mashing houses far more advantageously in working potatoes rich in starch.

The Botanical and Chemical Characteristics of the Potato Tuber.

If a potato be cut through transversely, the outer skin layer is clearly visible. The shell consists of thick-walled, cork-like cells, with dried-up protoplasm, shown at *a*, Fig. 4, and these serve as an outer protection for the tuber. The next layer (*b*) consists of thin-walled cells rich in protoplasm. Both these layers of cells contain no starch. Then follow strata of richly protoplasmic cells which contain a few small starch granules, and finally the cells of the farinaceous mass (*c*) containing the bulk of the starch.

The starch of the potato is held in suspension in the fluid contained in the cells, and is in the shape of white granules varying widely in size and form. The fluid consists of a solution of albumen, sugar, and mineral and organic substances.

By boiling, heating, or steaming potatoes the starch embedded in the cell juice undergoes a change. The granules absorb all the fluid by which they are surrounded, increase in size, and finally fill up the entire cell space. They then appear as a tough semi-transparent mass, and the starch is said to have gelatinized. It is in this state that the ferment of the malt, the diastase, can most energetically exert its saccharizing action upon the starch. Often, potatoes which are rich in starch do not contain sufficient water for proper gelatinization, and the distiller must, therefore, exercise great care in drawing off the amniotic or fruit water during the steaming process.

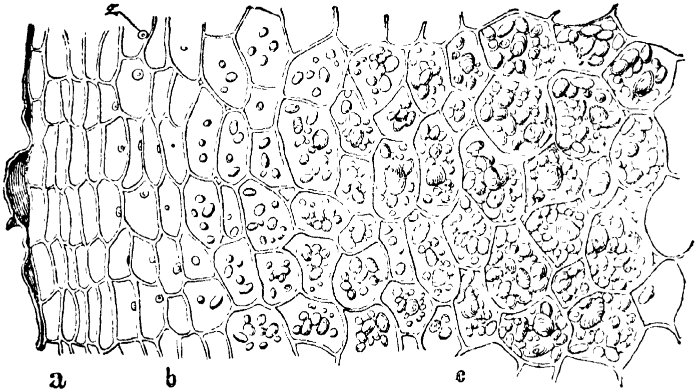

FIG. 4.—CROSS SECTION OF A POTATO MAGNIFIED 250 DIAMETERS AND SHOWING THE DIFFERENT LAYERS OF CELLS.

Besides starch the potato contains woody fibers, a little fat, and on an average about 1.070 per cent of mineral substances. The latter consist mainly of potash salts of phosphoric, hydrochloric, and sulphuric acids, potassium forming about 60 per cent of the ash of the potato.

The nitrogenous constituents of the potato, which generally form about 0.324 per cent of the mass, comprise, according to the investigations of C. Schulze, 19.2 per cent of insoluble albumen, 40.6 per cent of soluble albumen, and the remainder in the form of amides, 21.6 per cent being asparagin and 18.6 per cent amidic acids. Because of its large content of asparagin the potato is an excellent nutrient medium for yeast. Yeasts cultivated in potato mashes are characterized by great germinative power.

Unripe potatoes, richly fertilized with saltpeter or some other powerful nitrogenous fertilizer, often contain exceptionally large quantities of amides; these nourish the yeast so strongly during the working of the potatoes that the inconvenient foaming fermentation arises. This form of fermentation will be discussed more fully in connection with yeast preparation.

According to the investigations of Saare, potatoes contain, besides starch, 0.4 to 3.4 per cent of sugar and 0.74 to 0.95 per cent of pentosanes among the non-nitrogenous substances. The latter are gum-like bodies which, through hydrolysis, form sugars having five atoms of carbon, but which are not fermentable by means of yeast.

Vegetable acids, among them citric acid and the sour salts of oxalic acid, occur in the potato. These, together with the amides, give the acid reaction of potato juice. In examining the juices of many potatoes, Saare found that potatoes grown in rich soil gave mere traces of acid, while those cultivated in light or poor soil, on the other hand, were far more strongly acid. Naturally products of sour nature must arise when potatoes are steamed, for the acidity of the sweet mash varies between 0.2° and 0.9°, 1 degree corresponding to 1 cubic centimeter of standard soda solution necessary to neutralize 20 cubic centimeters of filtered mash. The juice of rotted potatoes is more strongly acid than that of the normal tuber.

2.—Phenomena During the Storage of Potatoes.

During storage potatoes should increase in starch content; this increase is, however, only an apparent gain in the percentage of starch, and is due to the loss of water. During protracted storage there is a loss in starch, as a part of the latter is liquefied and consumed by enzymes. According to the investigations of Müller-Thurgaus, three processes take place simultaneously in the potato: Loss of water through evaporation, conversion of starch into sugar by the action of diastatic enzymes, and destruction of the sugar through respiration, accompanied by the evolution of carbonic acid. The first and last processes cause losses; the remaining one does not. If the three processes balance, the proportional starch content is the same before and after storage. If the evaporation exceeds, the percentage of starch increases; if the respiration preponderates, it decreases. Absolute losses always take place. As respiration is less at decreasing temperatures and practically ceases at 32° F., the losses are correspondingly less the nearer the storage temperature approaches the latter point. The diastatic action, however, is affected very little by low temperatures. If the temperature falls below 28° F., the potato freezes. Frosted potatoes acquire a sweet taste, due to the formation of sugar caused by the interruption or checking of the respiratory process, while the conversion of the starch into sugar continues. In storing potatoes in a falling temperature there are three possibilities: If the temperature falls slowly to 32° F., the sugar formation continues, the respiration decreases, and the tuber becomes sweet. If the temperature falls below 28°, the potatoes freeze and remain sweet. If the temperature falls rapidly below 28°, the potatoes freeze but do not become sweet, as there was not sufficient time to permit the formation of sugar.

It should be a rule in storing potatoes to maintain the temperature at such a point that respiration and sugar conversion counterbalance; this is usually the case at temperatures between 40° and 50° F. The temperature should under no circumstances be permitted to fall below the freezing point, 32° F.

During germination the potato loses a considerable proportion of its starch, the loss varying between 3.18 and 9.88 per cent with germ lengths of 0.4 to 0.8 inch and 1.2 to 2.6 inches respectively.

Serious losses in the potato are also occasioned by diseases which cause the tuber to become soft and partially rotten. Wet-rotted potatoes lose a portion of the soft, starchy mass during washing. They are steamed with greater difficulty than healthy tubers, and are often the cause of impure fermentation.

Potato diseases and rot are due to certain fungi. According to the characterization of B. Frank, the principal of these include:

Phytophthora rot, which attacks the vine particularly and does not affect the tuber and the starch.

Rhizoctonia rot (Julius Kühn), which attacks the tubers and destroys the starch.

The rot caused by *Fuserium Solani* (Wehmer), which occurs when the vegetable is in ricks or bins, and is innocuous as far as the starch is concerned.

Nematoid or worm rot, caused by inimical animal organisms, and harmless with regard to the starch.

Scale or scurf upon the skin of the tuber; the cause of this has not yet been determined with certainty.

Lack of durability in a potato can also be ascribed to the disintegrating action of enzymes. The fungus disease is only a secondary occurrence called forth by the destructive activity of the ferments. Abnormal conditions of light increase this activity. Especially, however, is it due to the influence of the temperature; the "hotness" of the vegetable is the cause of the fungus growth.

The specific gravity of the potato varies according to its starch percentage, between 1.08 and 1.15; potatoes rich in starch have a higher specific gravity and a greater proportion of dry substances than less starchy tubers. Hence it is possible to estimate the percentage of starch in a potato by means of its specific gravity. The smaller the quantity of the other dry substances—albumen, vegetable fiber, and so forth—the more accurate will be the determination of the starch content by means of the specific gravity. The quantity of these substances varies but little, according to past investigations, principally by Behrend and Maercker, the mean being about 5.75 per cent. Thus, a higher content of dry substance in a potato indicates a larger starch percentage. As the quantity of starch is, however, not entirely constant, results may be obtained with this method which are not quite accurate; some of them may be 2 per cent out, one way or the other. As the carrying out of this method is simple and requires but little time, it is largely used in practice, notwithstanding the possibility of small errors in the results.

3.—The Investigation of the Potato with Regard to Starch.

The device most commonly employed for this purpose is the Reimann potato scale illustrated in Fig. 5. The determination of the specific gravity of a substance is based upon the fact that a body when weighed in a fluid loses in weight an equivalent to the weight of the mass of liquid displaced by the body. As the metric system of weights is based upon the weight of a determined volume of pure water—1 cubic centimeter of water weighing 1 gramme—it is possible to ascertain the volume, in cubic centimeters, of a body of specific weight by finding its loss in weight when weighed, in grammes, in water at normal temperature. For instance, 1,000 grammes of potatoes weigh, say, 125 grammes in water; thus they have lost 875 grammes in weight, and this figure represents their volume in cubic centimeters. Then, by dividing the absolute weight by the loss when weighed in liquid,

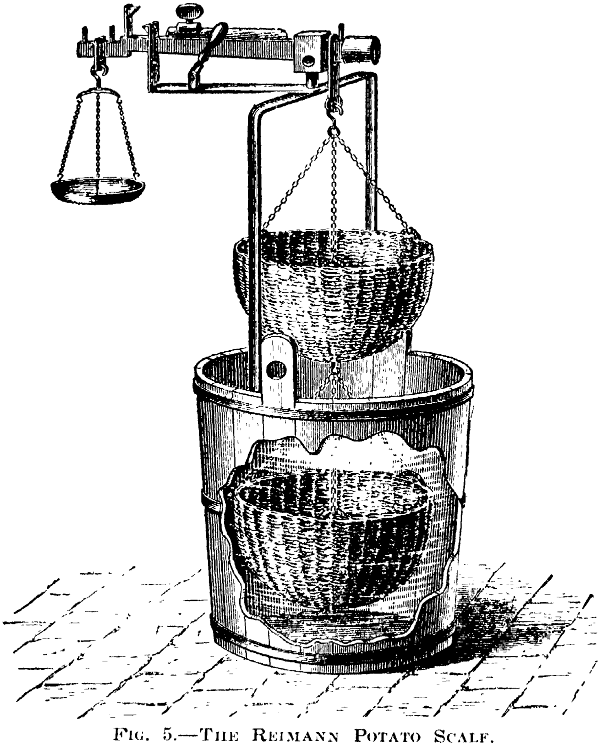

FIG. 5.—THE REIMANN POTATO SCALE.

the specific gravity is obtained as the result; thus 1000 ÷ 875 = 1.143.

The Reimann apparatus is a decimal scale, and carries at its shorter arm two baskets of wire netting arranged one above the other, the lower one dipping into a vessel filled with water. Exactly 5 kilogrammes (11.02 pounds) of carefully-cleaned potatoes are weighed off in the upper basket, and are then transferred to the lower one, where their loss in weight, equivalent to the water displaced, can be determined. The accompanying table gives the weights under water for the stated test weight of potatoes, with the corresponding specific gravities and percentages of dry substances and starch respectively.

In using the Reimann scale the following precautions should be observed:

1. The test sample to be taken from the mass of potatoes must be carefully chosen, as differences in the tubers often occur even in potatoes of the same kind, gathered during the same harvest.

The potatoes must be carefully cleaned and then dried. The latter operation is best accomplished by rubbing them with a cloth. Drying the potatoes by spreading them out in a warm place, for instance, on the boiler or the distilling apparatus, is liable to cause an error in the determination of the starch content. The potatoes may be weighed while moist, but in this case 2 per cent must be deducted from the resulting starch percentage.

2. The water used in the weighing must be pure and at the temperature of the room, about 63.5° F.

3. The lower basket must be dipped into the water before weighing the potatoes, and after the weighing must dip into the water to the same depth as before. Furthermore, in weighing, none of the potatoes should project above the surface of the liquid.

4. This method is not reliable for wet-rotted, diseased,

TABLE FOR THE DETERMINATION OF THE STARCH CONTENT OF POTATOES BY MEANS OF THE SPECIFIC GRAVITY (ACCORDING TO BEHREND, MAERCKER AND MORGEN.)

Weight of 5 Kilogrammes of Potatoes under Water.	Specific Gravity.	Content of Dry Substance. Per cent	Content of Starch Per cent	Weight of 5 Kilogrammes of Potatoes under Water	Specific Gravity	Content of Dry Substance. Per cent.	Content of Starch. Per cent.
375	1.080	19.7	13.9	535	1.120	28.3	22.5
380	1.081	19.9	14.1	540	1.121	28.5	22.7
385	1.083	20.3	14.5	545	1.123	28.9	23.1
390	1.084	20.5	14.7	550	1.124	29.1	23.3
395	1.086	20.9	15.1	555	1.125	29.3	23.5
400	1.087	21.2	15.1	560	1.126	29.5	23.7
405	1.088	21.4	15.6	565	1.127	29.8	24.0
410	1.089	21.6	15.8	570	1.129	30.2	24.4
415	1.091	22.0	16.2	575	1.130	30.4	24.6
420	1.092	22.2	16.4	580	1.131	30.6	24.8
425	1.093	22.4	16.6	585	1.132	30.8	25.0
430	1.094	22.7	16.9	590	1.134	31.3	25.5
435	1.095	22.9	17.1	595	1.135	31.5	25.7
440	1.097	23.3	17.5	600	1.136	31.7	25.9
445	1.098	23.5	17.7	605	1.138	32.1	26.3
450	1.099	23.7	17.9	610	1.139	32.3	26.5
455	1.100	24.0	18.2	615	1.140	32.5	26.7
460	1.101	24.2	18.4	620	1.142	33.0	27.2
465	1.102	24.4	18.6	625	1.143	33.2	27.4
470	1.104	24.8	19.0	630	1.144	33.4	27.6
475	1.105	25.0	19.2	635	1.146	33.8	28.0
480	1.106	25.2	19.4	640	1.147	34.1	28.3
485	1.107	25.5	19.7	645	1.148	34.3	28.5
490	1.109	25.9	20.1	650	1.149	34.5	28.7
495	1.110	26.1	20.3	655	1.151	34.9	29.1
500	1.111	26.3	20.5	660	1.152	35.1	29.3
505	1.112	26.5	20.7	665	1.153	35.4	29.6
510	1.113	26.7	20.9	670	1.155	35.8	30.0
515	1.114	26.9	21.1	675	1.156	36.0	30.2
520	1.115	27.2	21.4	680	1.157	36.2	30.4
525	1.117	27.4	21.6	685	1.159	36.4	30.6
530	1.119	28.0	22.2				

In the practice of starch manufacture the figures above representing the content of starch should be reduced by 1½ per cent.

unripe, shrunken, strongly-germinated, or otherwise abnormal potatoes. The determined specific gravities are too low in these cases. Frosted potatoes, even if thawed out, give results 1 per cent too high with the Reimann apparatus, according to Saare. Allowance must consequently be made for such errors in the final results.

5. The exact test weight of 5 grammes may be made up by using slices or fragments of a potato; but the submerging of floating potatoes by placing heavier ones upon them is not allowable, as such floating tubers contain cavities or spaces which render them buoyant, and they should, consequently, be cut up into smaller pieces.

It is advantageous to determine frequently the specific gravity of potatoes used in the distillery. Slight errors in testing are often counterbalanced in this manner, and average results which give reliable values regarding the starch content of the material to be worked, are thus obtained. When used in accordance with the rules stated, the Reimann apparatus will be found to be of the greatest value in every-day practice in the distilling plant.

In order to determine the starch content of potatoes indirectly by means of a saturated, common salt solution, the following method may be employed, according to Kroeker: Fill a vessel with pure water, and add thirty-five or forty carefully-cleaned potatoes to the water. Prepare a salt solution, using 1 part of common salt to 3 parts of water, and filter it. Pour this into the vessel containing the water and potatoes, and continue to add the solution until the potatoes, originally on the bottom of the vessel, remain suspended in any desired portion of the fluid. The specific gravity of the mixture of water and salt solution is now determined by means of a hydrometer, and the corresponding content of dry substance and starch in the potatoes will be found from the table given herewith. This method is inaccurate, and it is not advisable to employ it except in an emergency. The results are approximate enough to answer in such cases.

TABLE FOR THE SALT TEST ACCORDING TO KROCKER.

Saccharometer Degrees	Specific Gravity	Content of Starch	Content of Dry Substance	Saccharometer Degrees.	Specific Gravity	Contont of Starch	Content of Dry Substance
		Per cent.	Per cent			Per cent	Per cent.
17.0	1.070	11.5	17.1	25.0	1.106	19.4	25.2
17.5	1.072	11.9	17.7	25.5	1.108	19.9	25.7
18.0	1.074	12.5	18.3	26.0	1.110	20.3	26.1
18.5	1.077	13.1	18.9	26.5	1.113	20.9	26.7
19.0	1.079	13.7	19.5	27.0	1.115	21.4	27.2
19.5	1.081	14.1	19.9	27.5	1.118	22.0	27.8
20.0	1.083	14.5	20.3	28.0	1.120	22.5	28.3
20.5	1.085	14.9	20.7	28.5	1.122	22.9	28.7
21.0	1.088	15.6	21.4	29.0	1.125	23.5	29.3
21.5	1.090	16.0	21.8	29.5	1.127	24.0	29.8
22.0	1.092	16.4	22.2	30.0	1.129	24.4	30.2
22.5	1.094	16.9	22.7	31.0	1.131	25.5	31.3
23.0	1.097	17.5	23.3	32.0	1.139	26.5	32.3
23.5	1.099	17.9	23.7	33.0	1.144	27.6	33.4
24.0	1.101	18.4	24.2	34.0	1.149	28.7	34.5
24.5	1.103	18.8	24.6	35.0	1.150	28.9	34.7

To determine the starch content with greater accuracy, a number of potatoes, say twenty, should be tested separately or two at a time by the above method, and from the determined specific gravities the mean specific gravity can be derived with a fair degree of accuracy.

4.—Determination of the Dry Substance of Potatoes.

To ascertain the percentage of dry substance in potatoes, weigh a few of the tubers which have been carefully dried in air; cut them up into thin strips, and spread the latter out upon a plate. The strips are then carefully dried at 212° F. in a current of hydrogen until the weight remains constant. On subsequent weighing the difference between the first and last weights will give the loss in moisture, from which the percentage of dry substance can be determined.

5.—Dry Potatoes.

In order to provide a wider utilization of the potato, it has recently been converted on a large scale into a dry substance, by mechanical means, and it thus provides a durable material for various purposes, such as fodder for cattle and raw material in certain industries, especially as a substitute for corn in yeast manufacture. The dry potato is excellently adapted for the purposes of yeast manufacture by reason of the high percentage of nitrogen (according to Hayduck) that it contains. It is even superior to corn in this regard. In fact, the experiments which have been made in practice, following Lange's recommendations, have proven this to be the case. The yield of yeast was from 2 to 3 per cent higher than in the operation with corn, and furthermore, the quality of the yeast with regard to color and germinating power was far better than that of corn yeast. The alcohol yield is about the same with both yeasts, but the quality of the resulting spirit is probably superior when potato yeast is employed.

The samples tested by the Institution of Corn Distillers and Compressed Yeast Manufacturers, in Germany, gave the following results:

100 PARTS OF DRY POTATOES.

	Per cent in Sample Number					
	1	2	3	4	5	6
Water	17.40	11.14	24.12	18.68	18.10	9.53
Ash	3.40	3.29	8.05	3.75	2.35	1.12
Raw fibers	1.51	1.33	5.29	1.91	1.73	2.14
Protein	6.13	6.34	7.02	6.60	3.86	6.01
Fat	0.17	0.18	0.17	0.21	0.08	0.12
Non-nitrogenous extractive substances	70.57	77.72	55.05	68.85	73.88	78.08

II.—BARLEY.

The composition of barley is as follows:

	E. v. Wolff.	Dietrich and Konig		
		Minimum.	Maximum.	Average.
Moisture	14.3	7.23	20.88	13.77
Nitrogenous substance..	10.0	6.20	17.46	11.14
Fat	2.5	1.03	4.87	2.16
Non-nitrogenous extractive substances.	63.9	49.11	72.20	64.93
Woody fibers	7.1	1.96	14.16	5.31
Ash	2.2	0.60	6.82	2.69

Ninety or 95 per cent of the non-nitrogenous extractive substances of barley is starch, so that the starch content of the grain may be considered to constitute 60 to 62 per cent of the whole. Small or common barley, however, does not contain more than 57 to 58 per cent of starch. The weight of barley per bushel is, low 46 pounds, average 52, and high 56.

There is a number of varieties of barley; of these the commonest are:

Hordeum distichum, a large barley cultivated as a spring grain. It contains a high percentage of starch and little gluten.

Hordeum vulgare, the small or common barley. A winter variety of this barley is known as pearl barley. It is rich in nitrogenous organic combinations, and is suitable for the preparation of bread-stuffs and for similar purposes, but because of its high gluten content is hardly to be recommended for distilling purposes.

Hordeum hexatichum, or stock barley, generally grown as a spring grain, though to-day a variety called mammoth barley is sown in the fall. Stock barley is seldom used for distilling purposes.

Hordeum trifurcatum, known as square barley and naked or spoon barley. This grain is not bearded, and as it readily becomes too soft in steeping, it is not adapted for malting.

Hordeum distichum and *Hordeum vulgare* are mainly used for malt to saccharize raw materials.

III.—RYE.

The average composition of rye (*Secale cereale*) is as follows:

Moisture	14.3
Raw protein	11.0
Fat	2.0
Non-nitrogenous extractive substances	67.4
Woody fibers	3.5
Mineral substances	1.8

According to the analyses of Delbrück, the compositions of different varieties of rye are as follows:

	Water.	Starch.	Protein.	Ash.
Rye from middle Mecklenburg	15.2	61.1	7.3	1.82
Rye from northern Mecklenburg	15.5	62.1	7.7	1.85
Rye from southern Russia	11.1	59.0	12.0	1.35
Rye from Canada	14.4	61.6	8.5	1.77

The starch content of rye varies between 59 and 62.1 per cent, though infrequently the percentage is somewhat higher. Rye contains about 0.95 per cent of sugar and 4.86 per cent of gum and dextrin. The starch is similar to that of barley and wheat, but it cannot be isolated pure without great difficulty. The albuminous substances, according to Ritthausen, comprise gluten-casein, albumen, and mucedin. The same investigator demonstrated that if rye flour be mixed with a large quantity of water containing ½ per cent of potassium hydroxide at ordinary temperature, considerable butyric acid is rapidly formed. Rye which is rich in albumen is particularly well adapted for the purposes of compressed yeast manufacture. To render the albumen digestible for the yeast, the rye is slightly malted for two or three days, or is steeped, in a coarsely ground condition, for a considerable period in water containing dilute acid (about 1.4 ounces of sulphuric acid to 100 pounds of water) and at a low temperature. Through this steeping the rye loses its slimy character, and hence the subsequent fermenting process is a smoother one. This slimy character, according to Ritthausen, can be ascribed to the presence of a variety of gum having the chemical composition $C_6H_{10}O_5$. The small-grained albuminous rye is better suited for malting purposes in potato distillation than the large, heavy common rye, as the former gives a more richly diastatic malt.

IV.—CORN OR MAIZE.

Corn is largely used as a raw material in yeast and spirit manufacture, and according to Dietrich and König, contains:

	Minimum	Average.	Maximum
Moisture	7.10	13.12	22.10
Nitrogenous substances.	5.51	9.85	13.90
Fat	1.61	4.62	8.89
Non-nitrogenous extractive substances	60.49	68.41	74.92
Woody fibers.	0.76	2.49	8.52
Ash	0.61	1.51	3.93

The non-nitrogenous extractive substances of corn constitute about 68 per cent of the total mass and are nearly nine-tenths starch or other carbohydrates, so that the average proportion of starch in corn with a normal water content of 13 per cent is approximately 61 to 62 per cent. Often, however, corn contains a much higher percentage of water, and correspondingly, a smaller proportion of starch. Not infrequently corn contains as much as 20 per cent of water. The percentage of water in green corn is usually very high, often forming as much as one-quarter of the total weight. According to the atmospheric conditions obtaining and the methods of storage, corn seldom reaches its normal water content before six months or more have elapsed.

A microscopic examination generally shows the starch granules of corn to be simple and polyhedral or round in form. The first form alone appears in the external horny part of the grain, but both occur in the interior. The separate granules possess considerable density, are closely aggregated, and are considerably smaller than those of barley, and it is for these reasons that the gelatinization of the starch of corn is difficult to effect. The corn fat is reddish in color and frequently may be observed on the surface of mashes, where it can be diffused by boiling. The content of sugar and dextrin in corn is as high as 11.5 per cent and 4.8 per cent respectively. The protein substances in corn vary in composition, and usually possess different properties and characteristics from those found in other grain. The principal substances of these proteins of corn are corn fibrin and conglutin.

During transportation corn is often damaged by undergoing excessive heating, and grain so affected is usually very dry. In manufacturing processes where the quality of the spirit is of secondary importance, such corn can be used to advantage from an economical standpoint. Some experts maintain that European corn from the regions of the Danube is more easily worked than the American grain, and that the former gives thinner, sweeter mashes containing less spent malt and fermenting more easily. In practice it has been found, however, that the question of the locality in which the corn is grown is of less importance than the quality of the grain.

The determination of the starch content of corn cannot be accomplished by means of its specific gravity as in the case of potatoes, but requires a difficult chemical analysis, which can be performed only by an expert chemist. The reader is recommended to consult some good analytical industrial chemistry for the method of corn-starch determination.

V.—OATS.

Oats, *Avena sativa*, are largely used in the distillation industries for the preparation of malt, and furthermore, in the manufacture of yeast, as a substitute for barley. Oat starch, which constitutes 42 to 46 per cent of the whole, is materially different from that of other varieties of grain, the cells of the endosperm of oats containing truly compound granules, and other granules composed of large numbers of aggregated partial granules, both being of polyhedral form. It has on an average the following composition, according to Dietrich and König:

Water	12.37
Albumen	10.41
Fat	5.25
Non-nitrogenous extractive substances	57.78
Fibers	11.19
Ash	3.02

VI.—WHEAT.

It is well established that wheat yields a malt which is easily as rich in diastase as that from barley. It is, however, seldom used because of its high cost. Besides non-nitrogenous extractive substances—sugar, gum, and dextrin—wheat contains 50 to 70 per cent of starch, 7 to 21 per cent of albuminous substances, and 1 to 4 per cent of fat. According to Ritthausen, the nitrogenous substances of wheat include albumen, gluten-fibrin, gliadin, and mucedin, the last three forming the gluten which, when wheat flour is kneaded under water, still remains after all the starch granules and other substances soluble in water have been removed.

According to Dietrich and König, the composition of wheat is as follows:

Water	13.65
Albumen	12.35
Fat	1.75
Non-nitrogenous extractive substances	67.41
Fibers	2.53
Ash	1.81

VII.—RICE.

In countries where rice is inexpensive, it provides a valuable material for the manufacture of spirit. An aromatic beverage called arrac is distilled from it, the grain being disintegrated without the use of high pressure. When, however, the disintegration is carried out by steaming under high pressure, the resulting spirit is unfortunately rich in fusel oil. Rice provides the raw material for the rice wine of China and the *sake* of Japan. The starch of rice, which constitutes as high as 78 per cent of the whole, somewhat resembles that of oats, the separate granules being both simple and compound. When compound the granules consist of from 2 to 100 partial granules, generally of polyhedral form. The composition of husked rice according to Dietrich and König is as follows:

Water	14.0
Albumen	7.7
Fat	0.4
Non-nitrogenous extractive substances	75.4
Fibers	2.2
Ash	0.3

VIII.—OTHER RAW MATERIALS USED IN SPIRIT MANUFACTURE.

Among these are dhurra, or sorghum millet, cassava, chicory, figs, locust beans, horse chestnuts, and more largely, buckwheat. The composition of the last named is: Water, 12.63 per cent; albumen, 10.19; fat, 1.28; non-nitrogenous extractive substances, 72.15; fibers, 1.51; and ash, 2.24.

SACCHARIFEROUS RAW MATERIALS.

A--Sugar Beets.

The beet belongs to the family *Chenopodium* and genus *Beta,* the varieties generally cultivated being *Beta vulgaris,* the red beet, and *Beta cicla,* the white beet. The beet juice contains crystallizable sugar and, in solution, albuminous substances, mineral substances, asparagin, glutanin, betain, gum, fat, and coloring substances. The quantity of these constituents varies with the kind of the beet and the manner of its cultivation. For different reasons beets which cannot be advantageously manufactured into sugar may be utilized with profit for the production of alcohol, as the yield of the latter depends on the percentage of sugar alone, and is not influenced by the other constituents of the plant.

The sugar content of the beet is, on the average, 15 per cent, and not infrequently more. In fermentation, according to Lintner, one dozen average beets, containing 15 per cent of sugar, should produce about 2 gallons of pure alcohol. The mass of the beet consists of cellular tissue in which the juice is secreted in the form of a colorless liquid. The cellulose walls of the cells are to a certain extent coated with an intercellular substance, comprising chiefly pectin substances and tannin. The pith or fibers form about 1 per cent of the weight of the beet. The total quantity of the substances held in solution in the beet juice varies considerably, being generally from 12 to 18 per cent.

For distilling purposes the saccharometer is usually of sufficient accuracy for determining the sugar content of the beet juice, the general assumption being that the sugar comprises four-fifths of the dry substance indicated by the saccharometer.

B.—Molasses.

Molasses is the thick brown or yellowish brown syrup having a slightly disagreeable odor and taste, which remains behind as residue from the crystallizing processes in sugar manufacture. It contains from 45 to 53 per cent of sugar, which cannot be recovered in crystalline form by ordinary means because of the presence of combinations inimical to crystallization. Molasses from sugar manufactories where great care is exercised in crystallization the after products, contains less sugar. Because of the high percentage of sugar which it contains, molasses is well adapted for spirit manufacture. The sugar is in the form of cane sugar, and must be inverted by fermentation. The content of water varies between 10 and 25 per cent.

Besides sugar, molasses contains a number of nitrogenous combinations, including asparagin, glutanin, betain, ulminic and huminic substances. It contains no albuminoids, though nitrogenous and acid-like combinations, which form organic salts with potassium and sodium, are present.

The content of sugar in molasses may be approximately determined by the saccharometer, as in the case of beet juice. As molasses contains a number of optically active bodies, the results obtained by polarization are inaccurate. The other optically active bodies, of course, come into consideration in polarization, giving results too high or too low, as the bodies are either dextro-rotary or lævo-rotary. In the reduction of Fehling's solution, the presence of other non-fermentable organic substances, which also reduce the copper solution after treatment with hydrochloric acid, make the results obtained in this reduction too high throughout.

Sometimes molasses is rendered impure by the presence of bacterial spores, saltpeter, and volatile fatty acids, so that it cannot effectively be fermented by means of yeast. With good molasses and proper treatment it is possible to obtain 3 to 3.4 gallons of pure alcohol from 100 pounds of molasses. Molasses spirit contains by-products which are not found in potato alcohol. The separation of these is more difficult and necessitates greater expense than a similar operation with potato spirit, so that the price of raw molasses spirit is always somewhat lower than that of potato alcohol.

C.—Various Other Sacchariferous Raw Materials.

1. *Jerusalem artichoke (Helianthus tuberosus).*—The tubers of this plant contain directly fermentable levulose comprising, on an average, about 14 per cent of the whole, and about 2 per cent of inulin, a variety of starch which can be converted into sugar by steaming with or without acid.

2. *Sorghum saccharatum (Holcus saccharatus)* contains, according to the stage of its growth, levulose and crystallizable sugar, and when completely ripened crystallizable sugar alone. The content of sugar is from 6 to 15 per cent. It is cultivated and grown with great ease, and when matured under favorable circumstances attains heights of from 10 to 14 feet. Its use for purposes of distillation has been frequently advocated.

3. *Chicory (Cichorium intybus)* contains up to 24 per cent of carbohydrates, which can easily be converted into fermentable sugar, according to Dommerich.

4. *The gigantic carrot (Daucus)* has been recommended for purposes of distillation, as it is very easily produced and contains as high as 10 per cent of sugar and starch.

5. *Green corn stalks.*—Successful attempts have been made to produce alcohol from this usually waste material, and its employment for this purpose would appear promising.

6. *Fruits and berries* which contain sugar yield alcoholic distillates generally distinguished by agreeable taste and aroma. They are usually employed for the production of alcoholic beverages, and their use can only be remunerative where the operation permits of a fermentative period of longer duration and if the materials used are pure in sugar. The analyses of Fresenius give the following percentages of sugar for certain of the fruits:

	Per cent.
Plums	2.1
Green gages	3.1
Raspberries	4.0
Huckleberries	5.8
Currants	6.1
Damsons	6.2
Gooseberries	7.1
Pears	7.4
Apples	8.1
Sour Cherries	8.8
Sweet Cherries	10.8
Grapes	15.0

DIRECTOR OF INDUSTRIES
Bengal

PART V.

THE PREPARATION OF THE MALT.

1.—The Purpose of the Malt in Distillation.

IN working farinaceous raw materials, it is necessary to use malt in order to dissolve the gelatinized starch as well as to convert it into sugar. Starch is itself insoluble in water; the diastase, the enzyme of malt, first changes it into soluble starch, then into various dextrins, and finally into a variety of sugar, maltose, which, after disintegration into dextrose or grape sugar through the agency of the maltase of the yeast, is fermentable. The purpose of malt preparation is to produce the sugar-forming enzyme in the malted grain, as well as other enzymes capable of converting the insoluble nitrogenous combinations of the raw materials into soluble ones.

In malt preparation it is necessary, (*a*) to produce a malt rich in enzymes, particularly diastase, in order to effect the decomposition of starch and albumen with as little malt as possible, that is, as cheaply as possible, and (*b*) to obtain a malt as free as possible from micro-organisms, particularly those of injurious nature with regard to fermentation.

In order to produce an effective malt, the following considerations are of the greatest importance:

1. Good malting grain; usually the grain is barley and not infrequently oats and rye.
2. Water suited for this purpose.
3. Proper steeping apparatus for soaking the malt grain.
4. An efficient and well-constructed malt-house.
5. Proper treatment of the malt upon the malting floor.

2.—Materials Suitable for Malt Preparation.

The raw material generally employed for malt preparation is barley, followed in the order named, by rye, oats, and wheat. Wheat is used chiefly in Belgian distilleries, while oats are often employed for the purpose in Hungary. Under certain circumstance, rye and oats are well adapted for purposes of malting, though all other grains are not suited for malt preparation.

Grain which is to be used as malt should be chosen with the following characteristics in view:

1. It must not be fresh or still naturally moist; such grain cannot be utilized for purposes of malting as it is incompletely capable of germination, and cannot be sufficiently soaked in the steeping vat. Thus, the use of green grain should be avoided whenever possible.

2. The best malt is not prepared from full grained barley, rich in starch, even though this be best suited for brewing purposes; it is obtained from a flatter and lighter small-grained barley. Winter barley yields an excellent distilling malt. Because, however, this grain is poor in nitrogen, winter barley malt is not as rich in diastase as that prepared from summer barley; to obtain an equal diastatic effect greater quantities of winter barley must be used— about 20 to 25 pounds of barley for each 100 gallons of mashing capacity.

That small-grained barley yields better distilling malt can be ascribed largely to the fact that the smaller grains are richer in protein. A proteinous barley gives a strongly diastatic malt, as diastase belongs to the albuminoids and can only be produced from the albuminous substances of the barley grains. Even though it appear that all the albuminous substances of the barley grain are not available for diastase formation, nevertheless, those barleys which are richest in protein yield the best malts. The soluble albuminoids particularly appear to be directly concerned with the diastatic efficacy of the malt, as the following figures show. These are the results of an investigation made by Hayduck for the Association of Spirit Manufacturers of Germany:

	Soluble Nitrogen.	Total Nitrogen.
First Test, Best Malt..................	0.80	2.38
Second Test, Medium Malt........... ..	0.68	2.06
Third Test, Poor Malt.................. .	0.64	1.97
Fourth Test, Poorest Malt................	0.64	2.06

Up to the present time it has not been quite clear upon what conditions the enrichment in diastase through malting depends, for Lintner's researches merely established the fact that the nitrogen content of the barley does not determine the formation of the diastase. Hayduck's investigations, as set forth above, would appear to throw some light on the subject.

3. An important requirement for every variety of barley for malting purposes is the faculty of complete and regular germination. Grains incapable of germination are not only useless ballast, but are directly harmful as well to the fermentation as carriers of micro-organisms of destructive efficacy, for such grains are insoluble during the subsequent mashing process. Directly after harvesting every barley is temporarily incapable of complete germination; it does not attain its full germinative power until it has been stored in the bin for about two months. Here it undergoes an after-ripening, for immediately after the harvest only one-half of the grains of barley are germinative. The germinating power gradually increases, the barley becoming heated thereby, and after it has been stored for some three months it attains its maximum germinative efficacy. When barley is housed or stored under improper conditions, the grain undergoes chemical changes which reduce the germinative power considerably, the nitrogenous combinations as well as the carbohydrates being affected. At least double the quantity commonly

employed must be used when such is the case, and the grain should always, when so affected, be malted as soon as possible. Good barley should possess a germinative power of at least 96 to 98 per cent, and medium barley 91 to 93; that of poor barley is less than 85. It is quite true that poorer qualities of barley are often of necessity utilized in the distillery, but assuredly not to the advantage of the distilling operations, for it is usually impossible to make weakly germinative grains sprout properly. Hence, it is generally advisable to sell barley of this kind, even if at a loss, and to purchase good, germinative grain instead. Even the higher first cost is usually offset by the saving in malt and by the greater alcohol yield.

4. Barley with a thin skin or husk should be given the preference. While the interior of the barley grain may be mealy, glassy, or lardaceous, grain possessing the first mentioned characteristic should be preferred.

5. Barley with brown smut, infected with bacteria, and possessing a distinct odor should not be used for malting purposes. However, if the germinative power is still good, the development of the fungi and bacteria can often be suppressed during steeping by the use of disinfectants, such as milk of lime or sour sulphate of lime, so that it is sometimes advisable to attempt the production of malt from the grain. According to Heinzelmann, solutions of salicylic acid in the proportion of 1 to 10,000 can be used without danger as steeping water for poor qualities of barley. Solutions of acid sulphite of calcium may also be added to the steeping water and to that for cleaning the malting floor and vats. Some authorities recommend dilute solutions of antinnonin, dinitroorthocresol potassium (½ to 5 per cent), or hydrofluoric acid in dilute solution for disinfecting purposes. It is not advisable to use carbolic acid, as it not only imparts a dis-

agreeable odor to the alcohol but impairs the germinative efficacy of the barley as well.

6. It is extremely desirable to have the grains of regular and uniform size, for this assists in effecting smooth and even germination. This characteristic is often lacking in barley assigned for malting purposes in the distillery, and in this case the steeping should not be carried so far that the large grains, steeped with greatest difficulty, are fully saturated. Should such, however, be the case, the more easily steeped grains would absorb too much water. Hence the barley is steeped until the smaller grains have absorbed sufficient moisture, and later on the malting floor the remaining grains may be softened properly by sprinkling with water. Preferably, the small grains should be separated from the larger ones and each size malted separately.

7. It may be assumed, in general, that the most completely developed and, correspondingly, the best barley for malting is the heavy grain, running 54 to 56 pounds per bushel. However, varieties weighing from 48 to 50 pounds per bushel can be used successfully for distilling purposes if properly treated.

3.—Water in Malting and the Properties It Should Possess.

Water is employed in malting for the cleansing of the barley, that is, for the mechanical removal from the grains of adhering impurities, particularly micro-organisms inimical to fermentation, and their seeds. The impurities include seeds of weeds, dirt, and dust. Both the dust adhering to the barley and that floating in the atmosphere are dangerous in malting, as the former contains organic substances inclining toward putrefaction, and the latter carries the germs of plants of low organization, which are capable of acting as ferments and exciting lactic fermentation, and spores of fungi which may induce the formation of mold upon the green malt. Water is also utilized for steeping, that is, to provide the dry seed grains with so much moisture that they can begin to germinate, and, furthermore, that they can successfully carry on the sprouting processes.

Water suitable for both these operations must possess the same properties. Excessive care need not be taken in the selection of proper malting water, for any good potable water is adapted for this purpose. It is immaterial whether the water be hard or soft. At any rate hard water does no harm to the germination processes. In fact, certain considerations appear to indicate that hard water, that is, water containing lime, may even be of advantage; for during the steeping, hard water removes from the grains less of the organic and mineral substances necessary for germination, than soft water.

Water which contains a considerable quantity of organic impurities resulting from putrefaction and decomposition processes, is absolutely unsuited for malting. Such water can usually be readily recognized by its putrid odor. The impurity is generally due to drainings from cesspools and the water usually carries large masses of putrefactive and other bacteria which find a nutrient agar in the malt grains, develop thereby and, later, unfavorably affect the purity of the fermentation by their injurious efficacy. Such water contains substances due to the activity of these bacteria, and the presence of these substances alone should be sufficient to cause the suitability of the water for malting to be questioned. The substances include ammonia, nitrous, nitric, and chlorine combinations. Malting water should contain no sulphide of hydrogen or other sulphur combinations, for these are always the results of reducing processes which are due to bacteria or infusoria.

Ferric combinations, when in considerable quantities, retard germination. Water containing iron can, however, be used for malting; if the content of iron is very high the water can be improved by the addition of milk of lime or through aeration and filtration, whereby insoluble iron oxide is separated out. Finally, water which contains ordinary salt, calcium chloride, magnesium chloride, etc., is not suited for malting, as these salts retard germination.

4.—Washing the Barley.

From the standpoint of modern distillery practice, it is absolutely necessary to wash the barley, and this operation is carried out in every well-conducted plant regardless of the kind of barley used. The distillery is frequently dependent upon agricultural conditions and must be content with materials which under other circumstances would not be used. Thus it often happens that the distillery does not obtain the very best barley, as the latter can be sold at higher prices for brewing purposes. It must, therefore, make shift with poorer qualities of grain, and must at times even use barley which was rain-soaked in the field, which was improperly stored, or which suffered injury in some other manner. Barley of this character must be treated with particular care, and by no means must it be used for malting before undergoing an extremely careful washing process to remove adhering impurities. The success of the washing is more complete if, instead of dry grain, barley previously soaked for 20 or 24 hours is used. The reason for this lies in the fact that the initial soaking stretches the external skin of the grain tightly, smoothing out the wrinkles, and in the subsequent washing the spores of fungi lodged in these wrinkles are removed by the mutual friction of the grains. For this reason the steeping vats are so arranged that the steeped barley can be cleansed in them. In the cleansing process care must be taken not to injure the barley. The use of lime in washing can safely be recommended.

The most successful washing machines, which in nowise injure the barley and which thoroughly clean the grains, are those in which a whirling motion is given to the mass of barley and water by a current of compressed air forced therethrough so that the mutual friction of the grains themselves effects the cleansing process. According to Brannt a cleansing and sorting machine frequently employed, is constructed as follows: A wire cylinder—often also a pentagonal prism—revolves horizontally, or somewhat horizontally inclined, about a shaft upon which it is mounted. The cylinder is constructed of wire netting, with meshes of three or four different sizes, so that the barley, which enters the cylinder where the meshes are narrowest, in passing through is gradually freed from dust, seeds of weeds, and other impurities, and finally leaves the cylinder cleansed, grains of uniform size leaving the cylinder through the netting at different points. The cleansing may be rendered still more thorough by the use of an air blast.

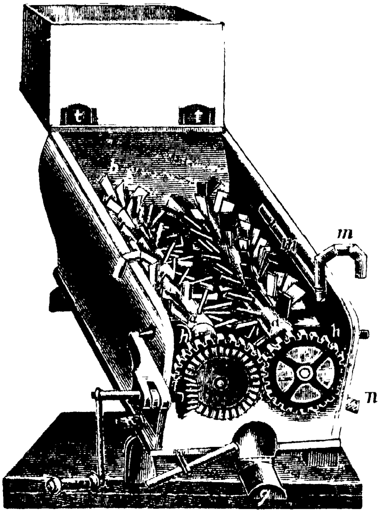

Fig. 6.—Machine for Washing Barley.

5.—The Steeping Vat and the Operation of Steeping the Barley.

Before the malt is ready for the floor it must absorb so much moisture that the germination can progress to completion under normal conditions. For this purpose the barley is brought into contact with water in the so-called steeping vat or cistern. It has been determined in practice that a steeping vat capacity equivalent to 36 gallons is necessary for each 100 pounds of barley. In malt preparation of longer duration a single vat is sufficient, but if the treatment is shorter two vats are necessary for alternate use. Such was formerly the case, though to-day this method has been generally abandoned. It is preferable, however, to have two vats available under all circumstances.

Steeping vats of wood or other porous material should be discarded. The wooden vats which were in former times generally used have been shown in practice to be worthless, as the organic substances dissolved by the water penetrate into the pores of the wood and there undergo putrefaction. Frequent and thorough scrubbing and whitewashing alone can keep these vats clean, and they are by no means durable. The steeping vats should be located in an inclosed space, preferably over the malting floors which are to be supplied with steeped barley from them, and should be well protected from frost. By locating the vats above the floors the barley need be transported but a short distance. Steeping vats constructed of brick, with walls faced with cement, are still occasionally to be found, though these, too, are inefficient. Vat construction in which the outlet opening for the steeping water is located at the bottom are quite useless. With this form of vat it is impossible to avoid the slow withdrawal of the water which filters through the barley, leaving therein the major part of the impurities which it carries. Heinzelmann recommends the following construction for steeping vats: The vessel should be of iron with a central, conical bottom. Above the latter is a second bottom comprising several cast iron plates; the second bottom is perforated and is mounted on suitable supports. Below this bottom is a perforated pipe which serves as a water inlet. The vessel is provided with upper and lower water outlet pipes and in front of the upper outlet pipe is located a small chamber having at the side or underneath, a wire net to hold back the grains carried by the current of the water. The vessel is filled with water and the grain is poured in with constant stirring of the liquid, the sterile grains remaining afloat on the surface. A strong current of water is now forced through the steeping grain from the lower inlet pipe, the mass being constantly agitated. By this procedure the impurities are washed away, and the sterile grains floating on the surface can be removed manually or in any other suitable way. To facilitate the emptying of a vat of this kind it is of advantage to provide a perforated bottom which is so hinged that upon the removal of a support it will automatically release the mass in the vessel and permit the same to escape rapidly therefrom.

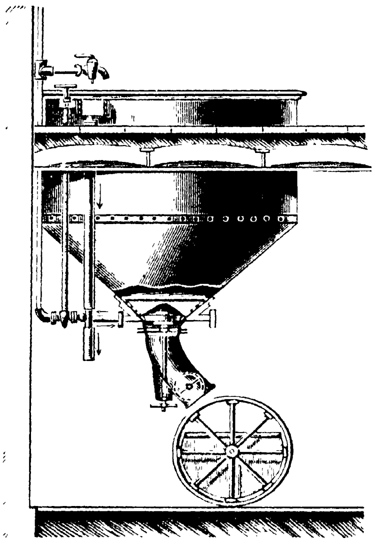

FIG. 7.—IRON STEEPING VAT WITH WATER INLET BELOW AND WITH CLEANSING APPARATUS.

The grains which at first rise to the surface of the water may include not only sterile grains incapable of germination, but sound grains as well which are brought to the surface by air bubbles. For this reason the grains floating on the surface should, for the first two or three hours, be submerged by means of the stirring paddles so that finally the sterile grains alone remain on the surface. These floating grains constitute what is known as skim-barley. This need not be thrown away after its removal, for it makes excellent fodder for cattle. It is uncertain what proportion of the entire weight of the steeped barley this refuse represents. While very little skim-barley results from the steeping of well-cleansed and assorted grain, the proportion may be as high as 3 to 4 per cent if badly cleansed barley is used. The amount of refuse also depends on the manner of steeping, and it sometimes happens that the amount is greater from properly steeped barley than from grain which has been negligently worked.

The barley is allowed to remain in the vat until it becomes saturated to the proper degree. The duration of the steeping depends upon the character of the barley grains and upon the temperature and chemical characteristics of the steeping water, and finally, upon the method of steeping as well. Mild, farinaceous barley softens sooner than horny grain, while a rich, thin-skinned barley requires a shorter steeping period than the full-grained, thick-skinned variety; the grain absorbs the moisture with greater rapidity in warm and soft water than in colder and harder water. In general, it may be assumed that the barley becomes sufficiently steeped within three days. In summer the grain may be ready in two days, while in winter the period may have to be lengthened to four days. Rye and oats can be steeped more rapidly than barley. The proper length of time for steeping has elapsed when the grain shows a mass of unsaturated substance in the farinaceous body, of about the size of a pin's head; this unsaturated mass can be distinguished by reason of its lighter color. Barley which has steeped too long germinates irregularly, while barley which has remained in the water for so long a period that it becomes "dead" will not germinate at all. By the admission of air during the steeping process subsequent germination is stimulated. Siemens recommends the alternate working of the barley with water and. exposed to the air, without water.

As mentioned before, the temperature and chemical composition of the water as well as the physical and chemical constitution of the barley, are the most important factors which govern the time required for the steeping of the grain. These considerations are of great importance and should be carefully studied by the maltster. The higher the temperature of the water and the softer it is, the more quickly will the barley be steeped, while the thicker the husk and the denser the tissue of the flour body of the grain, the longer will be the time required for steeping. As a rule the steeping in summer is from thirty-six to forty-eight hours in duration, while it lasts from three to five days in winter.

The following are among a number of fairly reliable tests for judging whether or not barley has been sufficiently steeped:

1. It should be possible to compress the grain between the fingers when the points are pressed toward each other.
2. In pressing between the fingers or in bending over a finger nail the hull should readily detach itself from the flour body.
3. In cutting with a dull knife the grain should not fly apart sharply, but should be pressed flat.

4. The streak of the cut or broken grain should be chalk-like.

In steeping, 100 parts of barley yield as a maximum 160 parts of steeped barley, on an average 140 to 145 parts, and as a minimum 130 parts.

It can be said that, as a rule, it is less dangerous an error to allow the barley to be insufficiently steeped than to carry the steeping process too far; for a lack of moisture during germination can easily be remedied by sprinkling the germinating grain, while at that period it is impossible to remove a superfluity of water.

The duration of the steeping period depends upon the degree of care with which the internal activity of the grain is nourished during the process. The metabolic or living force of the germ, which becomes active during the softening of the grain, and which manifests itself by respiration, requires the oxygen of the air for its development. Respiration is a process of slow combustion during which the grain absorbs oxygen and yields carbonic acid with the evolution of heat. It has been proven, particularly by the investigations of Schütt, that the carbonic acid evolved exerts a retarding influence upon the processes of germination, and, therefore, the carbonic acid should be removed by currents of pure air. The construction of the malting floors should allow of thorough ventilation; but the admission of the air must be regulated in such a manner that the germinating grain is protected from all strong drafts or from contact with cold layers of air. In the old method of steeping, oxygen was admitted in limited quantities only, each time the water was changed, and by means of the small quantities of air carried by the grains themselves between the husks. These quantities of air were, however, insufficient to provide the germs striving to develop with the necessary oxygen. To avoid this insufficiency a different method of steeping has been developed in recent times; this is known as "air-water steeping." In this method air is either forced through the steeping mass from below, or the mass is allowed to stand in free contact with the air to obtain the necessary oxygen. The latter operation consists in simply allowing the barley to stand alternately with and without water for periods of about six hours. This is the method recommended by Siemens, as said before. The respiration of the germinating grain is accelerated by this supplying of oxygen to such a degree that the grain begins to sprout in twenty-four to thirty six hours. When this occurs it is placed upon the malting floor, but as it does not contain sufficient water for complete germination, it is necessary to augment the supply of moisture by sprinkling the grain when spread out. Besides saving space and time, this method of steeping possesses the advantage of practically precluding the possibility of oversteeping. This was formerly a constant danger, particularly in working barley which germinated with difficulty and which was not uniform in grain. The quality of malt obtained by the air-water method is little inferior to that resulting from the other. Furthermore, the amount of malt refuse, according to Schneider, is less, and the germinating power is higher with the more modern process. Windisch also agrees with these views. Consequently the air-water method has come into widespread and successful use to-day.

While germination may take place at a temperature as low as 41° F., it is very weak and slow under these circumstances. The most favorable temperature for the germination of barley, and other varieties of grain as well, has been found to lie between 66° and 77° F. The germinative power of the grain becomes very much weakened and usually ceases entirely at points above 86° to 95° F. It has been shown to be of the greatest importance to maintain the definite temperatures most favorable to the various stages of germination. In practice comparatively low temperatures are generally employed, as slow germination, with its less intense combustion, saves starch and provides the malt with a higher proportion of diastase. At the same time the formation of organized vegetable ferments which would exert an injurious effect during the subsequent operations, is prevented.

6.—The Arrangement of the Malt House.

It cannot be emphasized too strongly that cleanliness and the elimination of micro-organisms injurious to fermentation should constitute the fundamental principle for the rational preparation of malt. If it is possible to obtain pure and effective malt, the subsequent operations in the process of spirit manufacture can be carried out with comparative ease; if, on the other hand, a mistake has been made during the preparation of the malt, this mistake invariably counts heavily later on and diminishes the subsequent yield of alcohol in an unmistakable manner. No matter how carefully the other operations are carried out, the art and knowledge of the distiller are almost always useless if he is forced to work with inferior malt.

For these reasons the malt house in which the malt is prepared must be of such construction and must be so maintained that mold, as well as putrefaction and fermentation arousing organisms, cannot be developed therein.

In order to be independent of external temperature changes, the malt house should preferably be sunk 4 to 8 feet below the surface of the earth. If necessary, it may be built upon the ground in the usual manner, but in this case it is, of course, necessary to provide heating apparatus to combat low external temperatures. Malting floors located above the ground are really to be recommended in such countries alone where the distillation is usually carried on, as in Germany, during the warmer months of the year. In a malt house built above ground, the walls must be of such thickness that an even temperature of 50° to 54° F. can be maintained without difficulty; the house should be provided with double doors and double windows. The windows should have effective shutters, or the panes of glass should be coated with a mixture of milk of lime and ultramarine to prevent the direct entry of sunlight. All the openings should be provided with wire netting or fly screens. The malt house should, of course, be provided with proper plumbing for the water supply as well as with suitable outlets for the waste water. The roof of the structure should preferably be vaulted.

The foundation of the malting floor is of the greatest importance. This must be impervious, smooth, and easy to clean, so that impurities of organized or unorganized nature cannot attach to it. Plates of heavy sandstone, burnt clay, Solenhofen slate, cement, or asphalt, have been found well suited for the purpose. The walls of the malt house must be so constructed that they can easily be washed with water; hard facing clinker cemented in place, or concrete rendered impervious by a facing which may be whitewashed from time to time, can be recommended. At the very least, the walls all around the malt house should be provided with a smooth facing of cement to a height of 3 feet. It is of advantage to provide the cement with several coats of a mixture of coal tar and asphalt in the proportions of 2 to 2½. Old plaster-covered walls should be repeatedly coated with oil or enamel paint to render the porous spots impervious and to enable the maltster to wash them freely with water. In a malt house of this construction mold or other fungus spots should under no circumstances be allowed to adhere to the walls, as they can, with little difficulty, be prevented or removed; they should be regarded as stains of dishonor, and the maltster should be severely censured for their presence.

A properly constructed malt house of the average, comparatively small proportions usual in the distillery, hardly requires artificial ventilation despite the carbonic acid developed during germination. It may happen, however, that a musty odor becomes apparent in the malt house; under these circumstances artificial ventilation must, of course, be introduced. This, however, should under no consideration be allowed to reduce the temperature to a dangerously low point, nor should it result in drafts with consequent inequalities in the temperature.

The malt house must be made sufficiently commodious for all purposes. This important requirement is, unfortunately, given too little consideration in practice, and often the malt house is proportioned for the most restricted operation, in the hope that should future distillation be on a larger scale, the floors available would be sufficient even in that case. This is a decided mistake to make. If the malting floor is not large enough, it is necessary to work the malt rapidly, to pile it up in heaps of considerable height. The natural result of this is an insufficient diastase formation, a too luxuriant growth of the malt, and a decided development of mold organisms and bacteria which later have a deleterious effect. Often the distiller is censured for the slow progress of the operation, whereas the fault really lies in the ineffective arrangement of the malt house. Consequently, the malt house should be so constructed that the distiller can work the malt according to all the proper regulations of the art and with the necessary low temperatures. A slow and cool working of the malt, which under no circumstances should be conducted at a temperature above

63.5° F., is a fundamental necessity for the production of a good, strongly diastatic malt.

To render possible a proper working of the malt—at the present time a twenty-day period is recognized as about the most favorable one—a malting floor approximately 20 square yards in area is necessary for each 260 gallons of mashing capacity—according to Heinzelmann possibly 25 square yards. There should be so much room that it is unnecessary to form the heaps up to the side walls, for at those points the temperature is usually lower than on the rest of the floor. A small channel should be provided at the walls to carry off the flow of cleansing water.

If the malting floor is not large enough for malting of this duration at low temperature, it is to be recommended that the malt be removed from the malting house for the last few days and dried or withered in an airy, well cleaned loft or withering floor, to prepare so-called withered malt.

7.—The Processes of Germination.

Germination is a life process which becomes externally visible through the formation of the acrospire and of the radicles. It arises under conditions of a definite content of water in the grain, a certain temperature, and of simultaneous contact with air. The water serves for the dissolution and transportation of substances. The necessary heat arises from the respiration, which depends upon the access of air. At the same time the respiration provides the force necessary for the formation of enzymes which dissolve and transmute the substances constituting the farinaceous body. This is the purpose of germination. The enzymes, in particular, must convert the carbohydrates into sugar (carbohydrate enzymes) and the highly molecular albuminous substances into simpler albumen combinations (albumen decompositive enzymes). Both of these are processes of great complexity.

1. The action of the carbohydrate enzymes during germination is as follows:

First, they dissolve the cell walls of the grain by means of the secretion-diastase (zytase).

Secondly, they dissolve the starch by means of the diastase, converting the starch first into dextrins and finally into maltose.

Thirdly, they transform the maltose into grape sugar through the action of the glucase.

Fourthly, they effect the reversion of the grape sugar into cane sugar.

Fifthly, they invert the cane sugar into dextrose and levulose.

And finally, they effect the reconversion of the starch.

Thus, besides the decompositive processes—the transformation of the starch into sugar—there are simultaneous formative actions and the starch is constantly being dissolved and reconverted.

2. Just as the starch is converted into certain varieties of sugar through the action of the diastase, so are the highly molecular albuminous substances present in the grain transformed during the germinating process into simpler combinations through the activity of the proteolytic (albumen decompositive) enzymes. This decomposition also, is effected gradually, step by step. At first non-diffusible substances (glutens), which are but partially soluble, are formed. The subsequent products of decomposition, the albuminoids, are, it is true, more fully soluble than the preceding ones, but they are nevertheless diffused with difficulty and, consequently, are of little value as regards the nourishment of the germ. The action of the proteolytic enzyme must

proceed still further before combinations result which are soluble without difficulty, which are characterized by a high degree of diffusibility, and which are, therefore, of great value for the growth and metabolic activity of the germinating grain. These are the peptones, particularly those combinations resembling the amides, and especially asparagin. As these substances are extremely valuable as nutrients for yeast, their presence guarantees that the malt will be effective for yeast preparation. In quantity they represent 20 to 30 per cent of the original nitrogenous substance in the grain. The largest relative proportion of the amides is found in the radicle (according to Kellner 23 to 34.9 per cent); the greatest absolute quantity is found in the body of the grain. The total quantity is naturally greatest in malt prepared from barley rich in nitrogen, and, therefore, such varieties of grain should be preferred for utilization in the distillery. The presence of the albumen decompositive enzyme in germinating barley has been experimentally demonstrated by Windisch and Schellhorn (Institute for Distillation Industries, Germany).

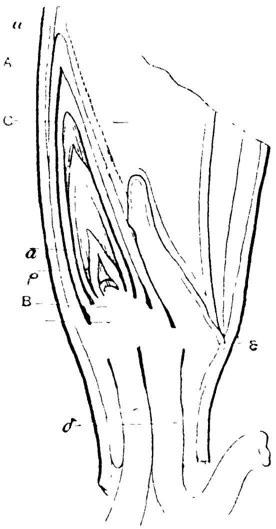

FIG. 8.—MAGNIFIED CROSS SECTION OF A GERMINATING GRAIN OF BARLEY.

Fig. 8 of the accompanying engravings illustrates a germinating grain of barley in cross section. *A* represents the envelope of the grain, consisting of the glume or husk, *B* indicates the embryo or germ, *C* the endosperm, the farinaceous body of the grain in which the starch is mainly located. The starchy cells of this farinaceous body are separated from the husk by a non-starchy glutinous layer which belongs to the starch body. The cells of this layer are angular and prismatic, with thick walls. The interior of these cells is fine in granule, dark gray in color, and is formed of albuminous bodies. The germ *B* contains the first organs developed by the young plant growing from the seed, for instance the leaf germ and the stem germ, destined to develop ultimately into the organs of the plant above the ground. This part of the embryo is known as the plumule or, in the distillation industry, as the aerospire. The roots are developed from the lower part of the embryo, *δ*, and are called radicles. Besides these, there are an enveloping layer, the target of scutellum, between the farinaceous body and the embryo, and the cotyledon which brings the substances dissolved during germination to the farinaceous body and thus acts as a carrier. The converted substances not only provide nourishment for the embryo, but they have the further task, particularly the carbohydrates, of supporting the respiration of the plant, and of providing the necessary force for the conversion of substances. This occurs through the oxidation of the carbohydrates, which thus make their latent forces available for the purposes of the plant growth. The quantity of carbohydrates consumed by the respiration may be as much as 17 per cent of the dry substance of the malt, in the slow working customary to-day.

Strong respiration of the germinating grain is only possible if air is freely admitted thereto. The products of respiration are carbonic acid and water. If large quantities of carbonic acid collect, the respiration and, consequently, the energy of the germination are decreased. The content of carbonic acid in the air of the malt house should never exceed 3 per cent. To insure that the air of the malt house does not contain a percentage of carbonic acid higher than this, proper ventilation may be resorted to. The more thorough this ventilation is, the poorer in carbonic acid and the richer in oxygen will the air for the malt be.

The evolution of heat grows correspondingly with increased respiration. This heat may even reach so high a point that the germination is completely destroyed unless means are provided for regulating it. Heat regulation can be effected through radiation and conduction, particularly by circulating air in the malt heaps. The air circulation depends upon the form of the heaps and the character of the husk of the grain. The smaller or thinner the heaps, the better will be the access of air to the grains. Grain, such as winter barley and oats, with bearded husks, develops less heat during malting because of better air circulation in the heaps than do naked grains, such as rye. The cooling effect of the air is greater if it is dry, as in this case the evaporation of the moisture is more effective. By frequently turning the malt and throwing the grains into the air during the turning, the temperature can be so regulated that it will not exceed 63.5° F. The barleys rich in albumen heat more readily than those of lower albumen content.

The development of the barley grain is illustrated in Fig. 9. The first grain shows the steeped but ungerminated condition. The next stage shows the rootlet or radicle breaking forth from the husk of the grain; it resembles a white point in appearance. The rootlet then separates into several branches and simultaneously, a distinguishable development of the aerospire begins. The latter forces its way along under the husk of the grain on the side opposite to the furrow, as illustrated in grain 3. The development proceeds as shown in grain

4. In the stage of development shown in grain 5 the aerospire has attained a length approximately three-quarters that of the grain, while the radicle is about 1½ times as long as the grain. At this point the malt is from six to eight days old.

Formerly malt was regarded as capable of utilization when in this condition; as such it may be characterized "short malt." It may be that with the methods employed in the distillery in former times, in which a great deal of malt was wasted, this view was not radically wrong; for it must be admitted that up to this point in the development but a short time was necessary and the danger of infecting the malt with micro-organisms harmful to fermentation was a slight one. This danger does not reach formidable proportions except in a longer period of growth, and it was formerly not understood how this danger could successfully be overcome. Doubtless the use of malt which had developed for a longer

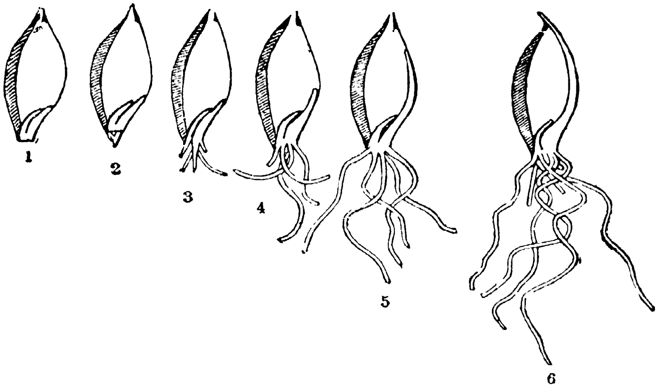

FIG. 9.—A GERMINATING BARLEY GRAIN AT DIFFERENT STAGES OF ITS DEVELOPMENT.

period was attended with very little success in many instances, and as the action and nature of the deleterious organisms were not understood, the unfortunate experiences were ascribed to the strong development of the malt. However, as it is now known from the investigations of Hayduck that the mass of the diastase increases greatly with the progress of the growth of the malt, it is customary, in order to obtain a particularly active malt, to prepare so-called "long malt" by permitting its development for twenty days or more. With increasing growth the acrospire advances from under the husk, as in grain 6, and gradually progresses further according to the degree of development to which the grain is permitted to advance.

8.—Treatment of the Grain Upon the Malting Floor.

If possible, the barley should not be removed to the malting floor until it has been sufficiently steeped. The methods of treatment upon the floor during the period of germination may vary considerably, but the procedure is usually as follows: After removal from the steeping vats the barley is allowed to lie for ten or twelve hours upon the floor to permit the water to drain off. It is then spread upon the malting floor in an even layer to a depth of 2 to 4 inches to permit the grains partially to dry on the surface. This preliminary drying can be recommended when the barley has been thoroughly steeped and when the temperature of the floor is a low one. After some twelve or fourteen hours the barley is formed into the so called *wet couch*, a smooth level heap from 8 to 20 inches deep, the higher the temperature the lower being the heap. Of course, if the barley has been insufficiently steeped and there is danger of its drying out too much, the grain may be heaped into a couch without previous spreading. To prevent an excessive rise of temperature in the interior of the couch, with consequent uneven sprouting, the barley must frequently be turned to keep all the grains uniformly moist. If the temperature of the malting house is warm or when the couch is of considerable height, the barley must, of course, be turned with greater frequency; on an average, the wet couch should be turned at least every six or eight hours.

The germinal parts of the barley begin to develop in from eighteen to twenty-four hours, or even after a longer period if the temperature is maintained at a low point. The visible state of growth is called *chilling*, and the couch is now characterized as a *broken couch*. When the radicles appear there is a perceptible rise in the temperature as the oxidation process becomes more active in the germinating grains. The barley in the interior of the couch appears moist; this is caused by the condensation of vapor formed during germination, on the upper, colder layer of grain. The wet couch is now characterized as a *young* or *growing couch*, and it is, from this time on, gradually reduced in height to 6, 4, 3, and even 2 inches, and when this has been accomplished it is called a *piece* or *floor*. The temperature of the air is the most important factor in regulating the height of the pieces, and if the season is warm the latter must be thinned out considerably by shoveling. Under no circumstances should the surface of a piece be increased too rapidly, for if too much water should evaporate the development of the germs would be interrupted before the proper time had arrived. The minimum depth of the piece should be reached just before the sprouting process is terminated. The floor area required for the final stages of green malt preparation increases in proportion to the increase in the bulk of the grain due to the growth of the radicles.

The pieces require frequent turning, preferably two to four times a day, to insure a proper air supply for the respiration of the germinating grain, as the growth proceeds with great rapidity in the pieces. In good malting, uniformity of growth is a prime essential, and this depends almost entirely upon aeration and regulation of the temperature. During germination the radicles should not grow too rapidly in proportion to the development of the aerospires. If the barley is carried at too high a temperature, this may take place. The hardness of the starch body should decrease in proportion to the development of the germ, and the germination should be uniform throughout the grains. The color of the latter should remain unaltered and the radicles should not fade, but should remain white and shiny. In case the germs commence to fade before the proper time the barley should be sprinkled with water. During the progress of the development of the germs all the above considerations should be given careful attention by the maltster.

9.—The Preparation of Long Malt.

The investigations of Delbrück and his collaborators have determined that the diastase content of barley comparatively poor in albumen is increased in the proportions of 100 to 128.5 if the malting lasts twenty days instead of a shorter time, as in the malting period formerly used in practice, while the increase in a barley rich in albumen is in the proportions of 100 to 160.5. The results of these investigations have been confirmed both by scientific research and in practice. It can no longer be doubted that through longer germination a more strongly diastatic and a more active malt is obtained; but certain considerations must be given careful attention in order to carry out this method properly.

Protraction of the germinating period does not always guarantee that a strongly diastatic and sound product will be obtained, and, therefore, it must be the specific purpose of long malt preparation to produce a powerfully active and healthy malt by the observation of all necessary precautions in carrying the operation for a longer period and at lower temperatures. The length of the development of the aerospire is comparatively immaterial in this regard. Long malt produced with rapid and luxuriant growth at higher temperature often yields a poor malt, as the germ has been developed out of its own mass and has not made use of the farinaceous body for its development. Furthermore, the formation of active enzymes has been retarded so that the dissolving and conversion of the substances were but poorly effected. The malt must have a strong and forced development, with internal consumption of as much as possible of the farinaceous body. The successful maltster is one who succeeds in producing the greatest diastatic power with the least possible development of the aerospire. The correct method is based on the principle of long working of the malt without allowing the aerospire to grow too freely or to attain too great a length. Under these circumstances the most effective consumption of the farinaceous body occurs, so that in the subsequent utilization of the malt no part of the starch fails to undergo decomposition.

For this purpose the malt is carried for a period of twenty days, notwithstanding that formerly it was considered sufficient to work the grain for six or seven days. Its powerful development is obtained by frequent turning. Of course, it is unavoidable that the malt should of necessity be frequently moistened, though not too strongly, during a germinating period lasting twenty days. Healthy development is achieved by regulating the temperature so that it shall never exceed 63.5° F. The development of mold fungi and bacteria is combated by soaking the malt grain in dilute milk of lime, using about 1 per cent of lime to the mass of barley.

The following method for the preparation of long malt is recommended by Hesse: After the barley has been removed from the steeping vat or washing apparatus, it is placed upon the malting floor in a heap, 2 to 4 inches thick, which is known as the wet couch. The external moisture which the grain carries must be removed by frequently turning the heap. In the operation of turning, the mass should be thrown into the air as high and loosely as possible, in order that the grains may come in contact freely with the air. The more frequently the wet couch is turned and the more energetically the operation is carried out, the sooner does the grain become dry and begin to grow. In this connection, of course, the moisture of the air and the outer temperature play an important part. It may sometimes happen that the wet couch will lie for five days without evincing the slightest sign of germinative activity. The growth now begins and manifests itself in the protrusion of small white points at the ends of the grains. The couch breaks and is now known as a broken couch. The white points of the grains gradually increase in size and develop into radicles. After a period of three to five days the radicles have increased to three or four in number; the acrospire develops on the opposite side under the husk, and after three to five days has attained a length equal to half that of the grain.

During this stage of its development, the malt is at the highest point of its living activity. Respiration and the development of heat are at a maximum. The radicles assume a strong form and begin to curl The grain should not be moistened during this stage of the development, and the water supplied to the grain during steeping must answer for the purposes of germination. The radicles should always be developed with the least possible quantity of moisture. They should show the handsome characteristic curl which usually is found in strong, diastatic malt. As a rule, additional moisture should not be supplied under normal conditions, until the aerospire has attained a length equal to that of the entire grain. In past years when this point was reached the development of the malt was considered sufficient; it was held to be a mistake to carry the germination so far that the aerospire became visible. To-day, with longer working of the malt a greater development of the aerospire cannot be avoided. The time at which the moisture should be added and the quantity of water with which the malt should be sprinkled depend primarily upon the duration of the working period. Furthermore, consideration must be given to the suitability of the malting grain, the humidity of the air, the temperature, and the season of the year. After all has been said, it still remains a question of the experience and knowledge of the maltster with regard to the time when the water should best be added to the malt. After the aerospire has broken through the husk the added moisture should be limited as much as possible. If this is done the radicles become drier and the vital action appears to cease; the heap, now known as an old couch, is allowed to lie upon the floor for several days longer, and if desired, may finally be withered before being used. In judging a malt it should be remembered that the diastase content is independent of the length of the aerospire, but depends upon the duration of the working upon the floor with moderate moisture and at a fairly low temperature. In general, if the malt is carried properly and in accordance with established rules, for a period of eighteen to twenty days, it is strongly diastatic.

As destruction of organic substances and development of carbonic acid occur during the germination of the grain, it is clear that the longer the malt grows the greater will be the loss in starch, for the destruction of the organic substances and the carbonic acid evolution are especially due to the decomposition of the starch and its conversion into sugar. This loss in starch constitutes about 6½ per cent of the starch content of the grain in short malt, while in long malt it approximates 17 per cent. Consequently, the proportionate yield of long malt is but 90 parts, while that of short malt is 100; but on the other hand, 63 parts of the former are equivalent in diastatic effect to 90 parts of the latter. *Thus, in spite of the greater starch loss the preparation of long malt is of undoubted advantage.* In almost all modern breweries long malt is used to-day, and its employment has enabled the distillers to effect a great saving in malt, sometimes as high as 50 per cent.

10.—The Preparation of Felted Malt.

Felted malt is to-day less generally used than formerly. Its preparation is as follows: The barley from the steeping vat or washing apparatus is piled in a level heap some 10 or 12 inches deep and is turned every six or eight hours with a shovel until the outside grains are apparently quite dry. The couch is then allowed to remain undisturbed until the radicles begin to show at the tips of the grains. The barley is now turned, is again spread out in a level heap about four inches deep, and is allowed to germinate without interruption until the radicles have thoroughly intermeshed and entangled. This is called felting. Lukewarm water should be sprinkled over the heap, if it appears that the upper layer becomes too dry before the under one has thoroughly felted. The malt is spaded into large square sections with flat wooden shovels, and each section is turned separately after the necessary water has been added. During the spading a number of grains, of course, fall from the malt, and these grains may be worked into a separate heap or may be used to fill the spaces caused by turning the heap. The degree of felting governs the duration of the working, and, as a rule, it may be said that the proper period has elapsed when the lower portion of the heap is more strongly felted than the upper.

To use felted malt either green or dry, it must first be torn apart. This is accomplished by simple machinery in which the pieces of felted malt are fed from a hopper against a rapidly-revolving shaft provided with sharp iron spikes or studs.

11. Some Practical Data for Malting.

1. *The composition of the malt embryo and of the malt itself.*

The figures giving the constituents and proportionate content of each, of malt with and without the embryos, will be found in a table at the end of Part VII.

2. *The water content of barley and of malt.*

	Minimum.	Maximum.	Average.
Barley	10.0	18.0	14.0
Steeped barley	40.0	45.0	42.5
Green malt	40.0	45.0	42.0
Air-dried malt	11.0	13.0	12.0
Kiln-dried malt	1.5	9.0	7.5

3. *The losses in malting and the malt yield.*

One hundred pounds of barley with 87 per cent of dry substance lose:

	Short Malt. (7 days.) Pounds.	Long Malt. (20 days.) Pounds.
In steeping	1.30	1.20
Dry substance during germination	5.14	11.57
Total loss of the green malt	6.44	15.87
Resulting dry substance from 100 pounds of barley	79.26	69.83
Green malt with 42.5 per cent of water	141.80	123.80

4. *Weight and volume alterations of the barley in malting and in drying or curing.*

	Volume. Parts.	Weight. Parts.
Barley before steeping	100	100
Steeped barley	145	148
Green malt	227	133
Clean kiln-dried malt	101	76
Malt germs	31	3.5

12.—The Preparation of Malt from Oats, Wheat, Rye, and Corn.

Malt can be prepared from all of these grains, and under certain conditions the product can be used to advantage, though recent investigations have demonstrated that in general other malts do not equal barley malt in diastatic power, and very seldom do they exceed it. For instance, the researches of Gläser and Morawsky gave the following relative values:

	Diastatic Effect.
Barley malt	100
Rye malt	93
Wheat malt	108
Oat malt	30
Corn malt	28

The same investigators obtained the following comparative results regarding the saccharizing efficacy of malt from different varieties of grain:

	Maltose.
Barley malt (two experiments)	14.416
Rye malt (one experiment)	13.433
Wheat malt (two experiments)	15.522
Oat malt (one experiment)	4.318
Corn malt (grown long)	4.062

1. *Rye and Wheat Malt.*

According to the foregoing figures, malt can be prepared from rye and wheat which, in regard to diastatic efficacy, compares favorably under the best conditions with barley malt. The considerations obtaining in the working of barley also come into play in the preparation of rye and wheat malt. Rye or wheat malt prepared at high temperature almost always possesses low diastatic power. The richer the wheat or rye is in proteins, the better is the malt prepared therefrom, according to the investigations of Hayduck. Both require steeping of short duration, rye from twelve to twenty-four hours at a temperature of 50° to 54° F., and wheat some twenty-four hours longer. Both grains not infrequently are sufficiently steeped after twenty or twenty-four hours. As they easily become moldy, it is advisable to treat them with milk of lime using about one per cent of lime to the mass of the grain during the first cleansing. To minimize the heating of the malt couches, it is sometimes advantageous to work with admixtures of oats or barley, say one part barley or oats to three parts rye or wheat, as the grains of both rye and wheat are not provided with beards and the husks are peculiarly thin and smooth. If possible, the duration of the germinating period should be about that of barley malt, and the temperature should be maintained between 59° and 63.5° F. Germinating rye

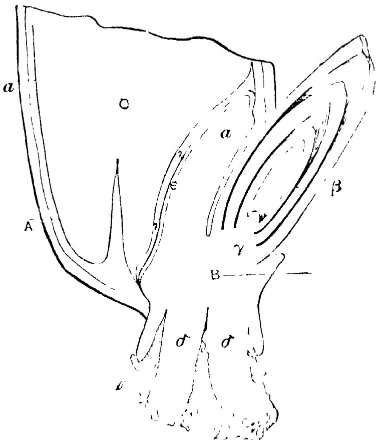

FIG. 10.—A MAGNIFIED CROSS SECTION OF A GERMINATING WHEAT GRAIN

and wheat grains present a different appearance from that of the barley grain, as they lack the resistant silicic husk under which the acrospire forces its way along in the barley. The acrospire, therefore, very soon breaks forth from the tender envelope of the rye or wheat grain, and bursts the shell, as is shown in Fig. 10. The reference letters indicate the same parts as in the corresponding Fig. 8 on page 88.

Long malt prepared from rye or wheat can be used to advantage for sugar formation in the mash, though it has been maintained that it is of less value in the manufacture of yeast. This can possibly be ascribed to the fact that rye and wheat grains do not possess bearded husks, for it has been established that the latter play an important part as means of transportation in the mechanical phases of yeast life. Nevertheless, excellent yeast has often been prepared under advantageous circumstances with rye malt.

2. *Oat Malt.*

According to Gläser and Morawsky, oat malt possesses but 30 per cent of the sugar-forming power of barley malt. Hayduck also found that even in the most favorable case investigated by him, it possessed but 50 per cent of the diastatic efficacy of the latter; from these figures it might be assumed that its use could hardly be recommended in the distillery. Nevertheless, experience has shown that its employment under certain circumstances is of advantage. Some light was thrown upon this question by a prize contest of the Association of the Spirit Manufacturers of Germany, which gave the following results: The best oat malt possesses a diastatic power decidedly inferior to that of barley malt. Fermentation is poorer when the barley malt is entirely replaced by oat malt. With a normal malt addition (4 to 5 pounds of barley for each 25 gallons of mashing capacity) one-third the quantity of the barley can advantageously be replaced by oats. Lack of diastase is not the reason why oat malt tends to minimize the danger of foaming fermentation. Certain phenomena of fermentation, for instance, this very formation of foam, may often be avoided by the use of oat malt, and thus to its employment can sometimes be ascribed particularly excellent fermentation and a large alcohol yield, if the distiller has, for these reasons, abandoned barley malt.

Thus, at times it is customary, if certain disadvantages cannot be avoided when barley malt is used, to employ oat malt as a remedy. In preparing malt it is not alone a question of sugar-forming efficacy, but malt is also regarded as the best nutrient medium for yeast. In this connection particularly is oat malt possessed of favorable characteristics. Exactly as oats are excellent food for growing and hard-working animals, it is of the greatest value, in a similar respect, for yeast. It has not yet been fully determined which of its constituents come into question for this purpose; particularly is it an open question whether the alkaloid of the oats (avenin) does or does not play an important rôle in this consideration. If it is true that oat malt is peculiarly adapted for rapid fermentation, the aggravating action may be ascribed to some substance contained in the oats, following the same line of reasoning as in connection with yeast. In fact, a number of investigations conducted by Delbrück, together with Deinhardt and Lange, has determined that the zymase content of the yeast is considerably increased by the addition of oat malt.

The preparation of oat malt is conducted on the same principles as that of barley malt. The steeping must be carried out with particular care, as oats become thoroughly steeped more rapidly than does barley. In general, oats require from forty to sixty hours for steeping. After this operation the grain is spread out in a thin layer to drain. After uniformly drying the oats are gathered in heaps 12 to 14 inches deep, and are allowed to germinate at a warm temperature for about five days.

Experience has shown, however, particularly in Hungary, that for oats a steeping period from thirty to forty hours in length may be sufficient. It has apparently been proven that it is advantageous to employ warm temperatures during germination and to carry the heaps comparatively high. Few attempts have been made to prepare long malt from oats, but it would appear from our experience in preparing long malt from barley, that carrying oat malt for a longer period would also be successful.

3. *Corn Malt.*

Corn malt plays an important part in distillation in those countries in which spirit is manufactured from this grain, or where barley is expensive or unobtainable. The diastatic power of corn malt is small, and according to Gläser and Morawsky is but 28 per cent of that of barley malt. Furthermore, corn easily becomes moldy and inclines toward the development of micro-organisms injurious to distillation, especially as the malt couches must be carried moist and warm (68° to 84° F.). Consequently, in the preparation of corn malt the very best grain only should be used, and this unfortunately is rarely obtainable.

Corn malt is extensively used in the United States. The grains must be steeped for at least three days, and often for a period considerably longer. A method of preparation commonly employed is that covered by Wolff's patent. In this method the grain is first exposed to moist air having a temperature of 96.8° F., in a heap about 4¾ inches deep, and subsequently, for a period of two or three hours, to dry air at the same temperature. When the corn is afterward cooled to 68° F. it will absorb 45 per cent of water in steeping, and requires a period of only thirty-six hours for this operation. The steeped corn is carried in 10-inch heaps upon a dark malting floor, and is turned at least once every twelve hours, the temperature being maintained at 70° F. When the radicles are about 0.2 inch long and the acrospire has just emerged from the grain, the germination is complete. In Hungary, where considerable corn malt is used, the grain is prepared by a thorough washing and preparative steeping. The steeping proper lasts for about fifty hours in water at a temperature of 68° F. Under these conditions the grain absorbs about 32 per cent of moisture. The malt is carried in 10-inch couches after chitting at a temperature of 86° F., and, if necessary, is sprinkled with water. The malting period is considered finished when the points of the radicles become yellow in color.

4. *Malt from Fungi.*

It is due to a recent discovery that we now know that certain fungi possess sugar-forming power, and can therefore be used in place of malt. The researches which have been carried out for the purposes of testing this discovery have been rather limited so far, but the following varieties of fungi have been studied more closely, with a view to determining their practical utility:

A. A Japanese mold fungus, *Eurotium oryzae*. This is cultivated in a suitable nutrient agar, such as rice or bran. It multiplies in a short time, and the diastase formation soon begins in the organism of the fungus. The diastase can be extracted with water, and used in the same manner as malt. According to the investigations of Delbrück, the diastase thus obtained was remarkably active, and it was possible to saccharize starch exactly as with grain malt. Its use in practice is still an open question, however.

B. *Amylomyces Rouxii*, possessing the same characteristics as the first-named fungus. Industrial utilization of this fungus has been carried out in large corn distilleries in Belgium, France, and Hungary. The fungus is cultivated in the mash itself. However, before a general introduction of this fungus into practice can take place, certain technical difficulties must be overcome. Up to the present time the researches conducted by Dr. Henneberg in the Institute for Distillation Industries, at the instance of Delbrück, have demonstrated little possibility for the use of this fungus in potato mashes.

13.—The Preservation of Malt Through Drying in Air and Kilns.

The barley by germination has become *green malt*, which must be used either at once or within a few days, provided nothing has been done to preserve it for a longer period. It must be turned frequently with the shovel and spread out in shallow heaps, if it is desired to keep the malt without change for even a few days. Lower temperatures and subsequent desiccation interrupt the germination of the grain and maintain the efficacy of the malt. It is not very long, however, before the formation of fungus growths sets in, together with lactic acid fermentation. To preserve the malt, the conditions favorable to the growth of fungi and mold must be obviated, and this can be accomplished by drying. When the malt is dried in the air in hot weather, it is called air-dried malt, and if the operation is carried out in a kiln the term kiln-dried malt is applied to the product. The latter contains 2 or 3 per cent only of moisture, while the air-dried malt contains as much as 15 to 17 per cent. Both air-drying and kiln-drying cause a certain loss in diastatic activity. This loss increases with the temperature at which the drying is conducted. According to Kjeldahl, the relative values are:

	Diastatic power of the dry substance.
Green malt	100
Green malt dried at 122° F.	88.2
Green malt dried at 110° F.	78.3
Green malt dried at 158° F.	52.9

Because of these severe losses in diastatic power, even with careful drying in air, it would appear to be justified in but few cases to prepare dry malt from green malt in any manner whatsoever. In hot countries it is, perhaps, necessary to use kiln-dried malt entirely. In temperate countries it is advisable to use green or, at the most, withered malt for the preparation of maltose, thereby not only saving labor and expense, but working with a more effective material as well.

To air-dry malt, it is spread out in a very thin layer upon the floor and turned at least every two hours, care being taken to break up all lumps. The operation can be successfully carried out on hot, dry days in warm rooms.

In preparing kiln-dried malt, the green malt should not be placed directly in the kiln, but should first be spread out on the floor to permit some of the moisture to evaporate, thereby better preserving the efficacy of the diastase. It would appear from Krauch's investigations that while the diastatic power of the malt may be considerably decreased by high temperatures while in a moist condition, its activity is little impaired when dry, even by temperatures as high as 257° F. Consequently, the drying should be commenced at a low temperature, and increased gradually from about 86° or 87° F. to 104° F. until the greater portion of the moisture has been removed.

The remainder of the operation may be carried out at a temperature of 122° to 131° F.

Well-dried malt should float upon water, and should not be much darker in color than the yellow of the barley; it should contain a mellow and sweet white starch body, and in biting through, it should crumble easily without being hard and brittle.

14.—The Quantities of Malt Necessary for Sugar Formation.

Before the preparation of malt was thoroughly understood it was necessary to utilize large quantities. It was customary to use 5 to 6 pounds of barley in the form of green malt for each 100 pounds of potatoes. This barley is equivalent to a mass of green malt weighing from 7 to 7½ pounds. Of the latter, some 3 pounds, corresponding to 2 pounds of barley, were used for the preparation of yeast, and about 4 pounds, say 3 pounds of barley, for the mash. Another reason for using such large quantities of malt lay therein that the diastatic power of a considerable part of the malt was injuriously affected because of inefficient mashing apparatus, in which the equalization of the temperature was slow and incomplete and wherein the mash was overheated in parts. This was called the scalding of the malt. These conditions were changed by the introduction of the exhauster in connection with the Henze apparatus, as well as by the powerful stirring devices introduced with modern mash vats, so that today instead of 6 pounds of barley, at most 4 to 5 pounds are used. Recently a still greater saving in malt has been made possible because of the increased diastatic power of the malt produced by long malting, so that in a properly conducted distillery provided with the best apparatus but 2 to 2½ pounds of malt grain for each 100 pounds of potatoes are necessary for sugar formation and yeast preparation. In measuring the malting grain, it has been found of advantage to use the mashing capacity as a basis, instead of the quantity of potatoes to be mashed. In this method allowance for the fact that more malt must be added to potatoes poor in starch than would apparently be necessary according to the quantity of mashed starch, is avoided. To-day it is considered good practice to use 4 to 5 pounds of malt grain for each 25 gallons of mashing capacity.

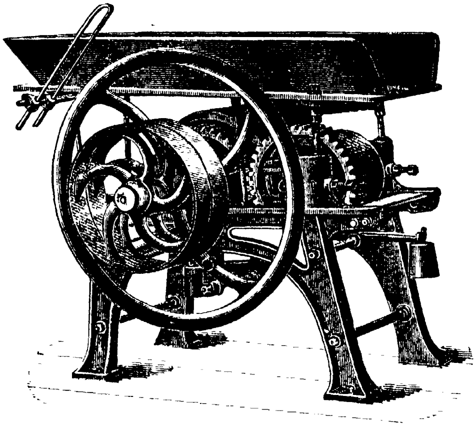

FIG. 11.—GREEN MALT CRUSHER.

15.—Comminution of the Green Malt.

1. *Malt Crushers.*

To bring the malt rapidly and completely to an active condition, it must be comminuted as finely as possible, both for the preparation of the yeast and for the formation of sugar. This operation is generally carried out to-day with malt crushers. The malt crusher usually consists of smooth iron rolls provided with adjustable bearings, so that they can be set any desired distance apart, or can be withdrawn when they are worn out. Devices for effecting the self-adjustment of the rolls have not been successful.

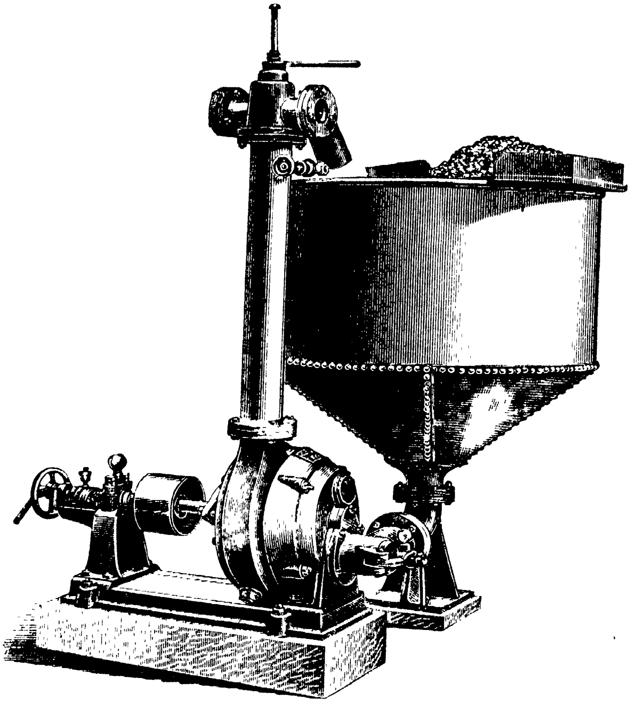

FIG. 12—MALT MILK APPARATUS OF THE BOHM TYPE.

To break up the malt as completely as possible, rolls of equal size are no longer used, but instead a larger and a smaller roll are employed, so that a point on the surface of the larger roll moves more rapidly than the corresponding point on the surface of the smaller one, and a dragging and tearing action is thereby obtained. The rolls must be carefully fashioned and must be well mounted. Any injury to the rolls due to foreign bodies, such as pieces of iron, must be remedied without delay. To avoid rapid deterioration the crushers are provided with special bearings. Fig. 11 illustrates an apparatus which has been found efficient in practice.

2. *Malt Milk Apparatus.*

The first apparatus of this kind was constructed by C. G. Bohm, of Fredersdorf, Germany; it is illustrated in Fig. 12. It comprises a wrought-iron malt vessel with a conical bottom; with this is connected a centrifugal mill, which can be driven with great rapidity by means of belt and pulley and which, at the same time, is adapted to act as a pump. The malt which is placed in the vessel with a proper quantity of water is drawn into the mill, broken up, and thrown back again into the conical vessel. This operation is repeated until a fine malt milk is obtained. The malt milk apparatus does not, however, render possible a more complete comminution of the malt than is effected by an efficient malt crusher, but the work performed per unit of time is greater. Malt milk apparatus will be found useful where rapidity of operation is desired and where dilution of the mash is unimportant, for instance, where there is no tax on the mashing capacity.

PART VI.

STEAMING THE RAW MATERIAL.

I.—THE WORKING OF POTATOES.

1.—Washing the Potatoes.

THE potatoes must first undergo a cleansing process in washing apparatus in order to remove adhering dirt and sand. This operation must be carried out with exceeding care, for through the removal of the attached impurities the general cleanliness of operation is enhanced, and deterioration of mashing and distilling apparatus is minimized. Before the potatoes undergo the washing itself they pass through a slatted drum, and are tossed about by the rotating movement of the same to free them from loose adhering earth. They escape from the drum through two or three openings in the body, and enter the water trough in small quantities; here they are gradually forced toward the opposite end of the trough by re-

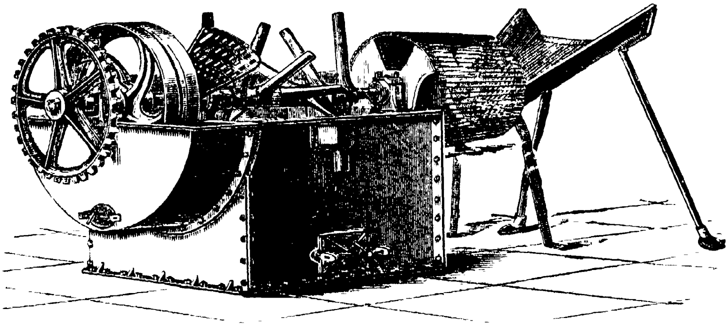
FIG. 13.—POTATO WASHER BUILT BY ECKERT, BERLIN, GERMANY.

volving stirring-arms. In the trough they are washed by a current of water flowing in a direction opposite to their movement. The cleansed potatoes are thrown into elevator buckets by means of lifting blades; the elevator removes the material to the Henze apparatus or to a scale located between the washing machine and the latter. Fig. 13 shows a form of potato washer largely used in Germany. To accomplish a thorough cleansing of the potatoes, the washing operation must be of sufficient duration. It has been found that if the apparatus is about 9 to 12 feet long, the washing is effected with the necessary thoroughness.

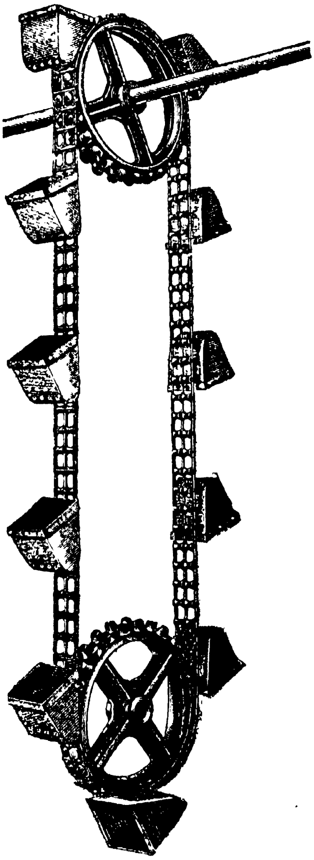

FIG. 14—BUCKET HOISTER FOR POTATOES.

The washing apparatus is most advantageously located in the receiving room of the distillery, so that the potatoes can be shoveled directly into the drum. In many plants washers of the kind used in sugar manufacture have been installed for the transferring and preparatory cleaning of the potatoes. They are to be particularly recommended for use with potatoes grown in heavy soil; the latter are seldom properly cleansed with a single washing. Every properly-conducted distillery should be provided with an apparatus, installed between the elevator and the steamer, for weighing the potatoes. For this purpose a simple wooden or iron receptacle mounted upon the platform of a decimal scale and provided with a trap door, has been found to be all that is necessary to weigh the potatoes before steaming. Automatic scales, such as those constructed by C. Reifert, are frequently employed in Germany.

2.—*Steaming the Potatoes.*

The potatoes are steamed for two reasons:

First, to effect the conversion of the starch to a gelatinous or, preferably, dissolved state. As has been repeatedly mentioned, unsteeped starch can be but slowly dissolved by the diastase of the malt, while starch in a gelatinized condition is dissolved almost instantaneously.

Secondly, to effect the destruction of the walls enveloping the starch granules, that the contents of the cells may be completely gelatinized and available for the action of the diastase.

As potatoes contain 76 parts of water to 18 parts of starch, the natural moisture is entirely sufficient for the conversion of the starch to the gelatinized condition at a cooking temperature of 212° F. Consequently, in cooking and steaming potatoes no water need be added; on the contrary, it is even necessary for the production of a thick mash that the condensed water, as well as the amniotic water or natural juice of the potatoes, should be withdrawn as largely as possible during the steaming operation. The remaining quantities of water are sufficient for the desired gelatinization or dissolving under high pressure. The latter is necessary in order to secure the rapid and complete dissolving of the starch. In working grains with a low percentage of water, the situation is different; these contain but 13 to 15 per cent of moisture, and about 60 per cent of starch, so that in steaming them water may be added. Potatoes can be steamed either in open vessels, that is, receptacles from which steam at ordinary pressure can escape, or in steam-tight, high-pressure apparatus.

A. Steaming at Ordinary Pressure.

Until the year 1871 potatoes were steamed exclusively at ordinary pressure, that is, without the application of steam under high pressure. The apparatus used for this purpose was a potato steam drum of wood. To-day this, as well as the method of its operation, is but of historical value. The operation of this apparatus was very unsatisfactory as compared with the process of to-day, in which the high-pressure apparatus, the Henze steamer, is utilized.

B. Steaming Under High Pressure.

High pressure was first used in the year 1871 in the Hollefreund apparatus, the inventor of which is said to have been an engineer named Schultze, of Pesth, Hungary. The Hollefreund apparatus, as then constructed, was expensive and required considerable power for its operation; such power was usually not available in small distilleries. Hollefreund's apparatus comprised the following parts, as indicated in the accompanying Fig. 15: *A*, cylinder; *B*, dome; *C*, manhole; *D*, stirring shaft; *d d d*, stirring arms; *E*, loose pulley; *F*, driving pulley; *G G*, bearings of the stirring shaft; *H*, discharge pipe for condensed water and mash; *J*, pressure gage; *K*, vacuum gage; *L*, safety valve; *M*, pipe for the admission of malt; *m*, valve for *M*; *N*, valve for the admission of air; *O*, pipe to the condenser; *P*, pipe for the admission of water; *a a*, pipes for the introduction of steam. For the reasons given above, the apparatus was unsatisfactory; therefore Henze determined to attempt the steaming of potatoes without mechanical power in the specially-constructed steamer which now bears his name. Since 1873, when it was first discussed at the general assembly of the Association of German Spirit Manufacturers, this device has come into almost universal employment; only here and there is some other apparatus to be found in a distillery, and then for special reasons only. The advantages of the use of high pressure over the old processes are substantially as follows:

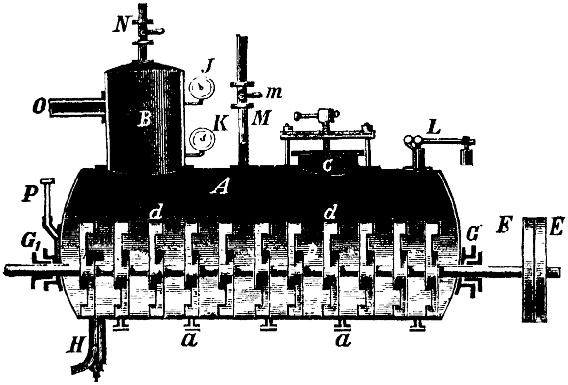

FIG. 15.—HOLLEFREUND'S STEAMING APPARATUS.

First, the old method, incomplete and mechanically poor in arrangement, has been replaced by a simpler process, which is based on scientific principles and is technically well elaborated.

Secondly, with the old process, under favorable circumstances, 5 per cent, though usually 7½ to 10 per cent, of the starch of potatoes and 10 to 12 per cent of that of the cereals, remained undissolved. With the employment of high pressure, it can be said that practically all of the starch is dissolved if the operation is properly conducted and the raw materials used are suitable and well prepared.

3.—High-Pressure Apparatus.

A. The Older Systems.

The older systems of this character, among which those of Hollefreund and Bohm deserve especial mention, are to-day no longer used in distillation. The modern, perfected construction, which is now used in practically every distillery employing high-pressure apparatus, is that evolved by Henze and, in contrast to the older apparatus, it possesses the advantages of cheapness, simplicity, and great capacity.

B. The Henze Steamer.

a. The Arrangement of the Henze Apparatus.

The steamer used by Henze himself when he first devised his system consisted of an old boiler set up on end and provided interiorly with a conical wooden bottom. In its present construction it is either purely conical in form, or possesses an upper cylindrical part to which is attached a lower conical part. In the distillery at Mockau, Germany, this construction was employed as early as the spring of 1873 by Gontard, and was built in accordance with data given by Henze himself. Among the machine manufacturers, H. Paucksch, of Landsberg, Germany, appears to have been the first to construct a steamer with a conical lower section, and the first apparatus built by this manufacturer was erected in the distillery of Bärwalde-Neumark. Later Paucksch constructed the apparatus of conical form, and this was patented in 1878. As this form has shown itself to be effective as far as the distribution of the steam is concerned, the Henze apparatus which were constructed after this approached the nearly conical form as far as possible. It is possible, however, to carry this construction too far, for it is, of course, necessary to make this type much longer than the partly cylindrical form to obtain equal capacity and, therefore, the height of the steamer may easily become such that the apparatus cannot be set up in the distillery without great difficulty. Consequently, the very pointed construction has lately been abandoned to a certain extent. Fig. 17 illustrates the latest form of Henze apparatus as constructed by H. Paucksch, Germany.

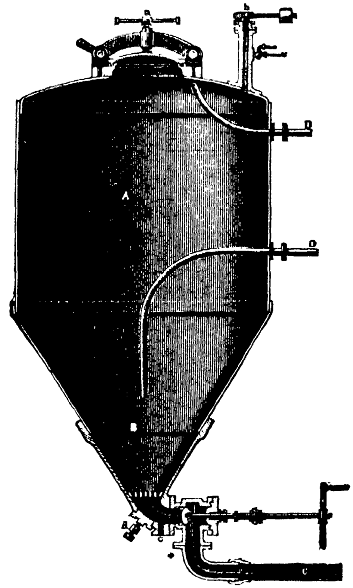

Fig. 16.—Cylindrical Henze Steamer With Conical Bottom.

The Henze apparatus comprises a number of parts which are absolutely essential for its operation. These include a steam inlet pipe at the upper part of the body to steam the contents from above, and a similar pipe at the lower part of the body to steam from below, a cock at the lower part of the cone to draw off the condensed and natural water, a manhole at the top for charging with raw material, a safety valve, and a blow-out pipe at the lower part of the cone. The blow-out

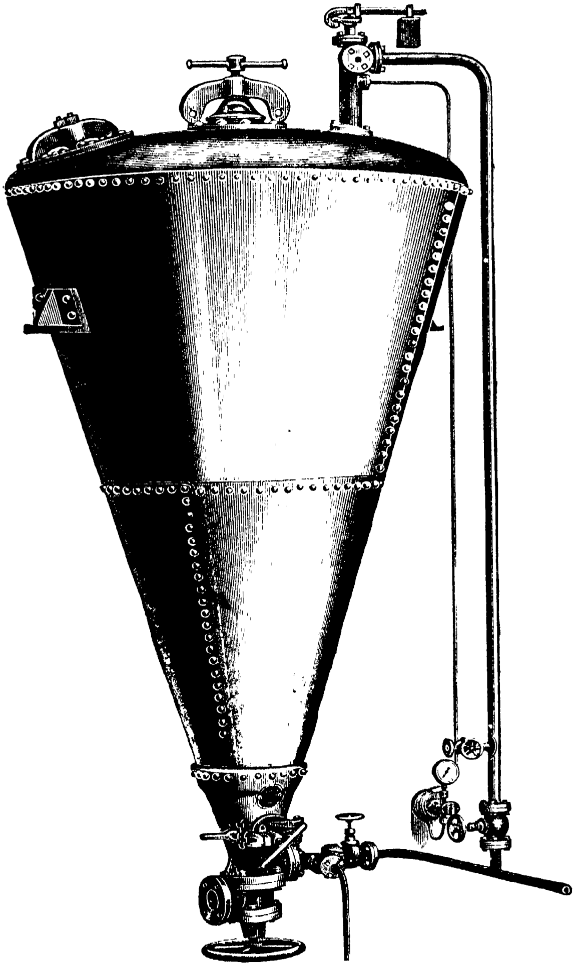

FIG. 17.—MODERN HENZE STEAMING APPARATUS OF CONICAL FORM.

pipe has a sharp-edged grate or valve for breaking up the contents as the mass is blown out. The cone wall is provided with an opening for the removal of stones and other foreign bodies, and on the upper part of the body are mounted a pressure gage and an air cock.

b. The Operation of the Henze Apparatus.

Steaming Potatoes Under Normal Conditions.—Before beginning to steam, the body of the apparatus must be filled somewhat above the usual height with water, and the pressure must be raised to the highest permissible point. The manhole of the steamer, which has been filled with potatoes, is then closed, the upper air cock and the outlet cock for the natural water are opened, and steam is allowed to enter the vessel through the upper inlet pipe. As soon as steam escapes from the upper air cock the latter is closed; water now flows still more freely from the natural water cock, and as soon as the potatoes have been heated through to the bottom of the apparatus, steam and the air remaining in the vessel also escape from this opening. The water cock is now closed, though it may be opened temporarily from time to time to withdraw the natural and condensed water, usual with concentrated mashes and with potatoes poor in starch, and steam is allowed to flow through the upper steam inlet pipe until a pressure of 1½ to 2 atmospheres has been reached. To avoid starch losses, the amniotic and condensed water last withdrawn from the apparatus is allowed to run into the preparatory mash vat. The upper steam valve is now closed, and the steam is permitted to enter through the lower inlet pipe until a pressure of 3 atmospheres is reached. After standing at this pressure for 10 or 15 minutes, the apparatus is blown out, the lower steam inlet being closed, while the upper inlet and the blow-out valves are opened. The blowing out must under all circumstances take place at the highest pressure, that is, 3 to 4 atmospheres, so that the potato mass may be thoroughly broken up. The rapidity of the blowing out depends upon the efficiency of the mashing vat, especially upon the cooling. In general, the blowing out should last 45 to 50 minutes. Steaming and blowing out together require about two hours. It is advisable to regulate the pressure so that the safety valve blows off steam constantly, though slightly, during the entire operation. This should always be the case if the potatoes are very rich in starch, for they are then kept in constant motion and become disintegrated more rapidly.

Steaming Potatoes Especially Rich in Starch.—In steaming potatoes very rich in starch, it generally happens that the disintegration can be accomplished only when certain rules are observed. For one thing, the natural water should not be drained off too freely. It is advisable at first to steam rapidly from above with the natural water cock open until the steamer has become heated through from above to about the middle point, some fifteen minutes being necessary for this to take place. The natural water cock is then closed and steam is permitted to enter the apparatus from below slowly, until the pressure increases to 3 or 3½ atmospheres. The remainder of operation is conducted as described above.

Steaming Frozen or Wet-Rotted Potatoes.—Great difficulty is often encountered in the complete disintegration of frozen or wet-rotted potatoes. The cause of this is the fact that such potatoes in steaming become soft and aggregate, and consequently are insufficiently acted upon throughout by the steam. The higher the pressure and the greater the rapidity with which the operation is carried out, the greater become the difficulties. It is advisable to begin steaming very slowly, and to permit the steam to flow through the apparatus for about one hour with open outlet valves; subsequently, the operation may be conducted at higher pressure, up to 3 atmospheres, for about half an hour. Despite all care, it nevertheless often happens that large masses of the contents are not sufficiently disintegrated. This becomes apparent during the blowing out by the appearance of steam, now and then, instead of the potato mass, or by the decided crackling which can be heard at the outlet valve. Under these circumstances, it is advisable to allow steam to enter the apparatus while the blowing out is taking place. Even if the steaming is protracted by this, the losses will be found to be smaller in the end.

c. Proportions of the Henze Apparatus.

For each hundredweight of potatoes rich in starch, a capacity equivalent to 18 gallons is necessary in the Henze apparatus, while for potatoes poor in starch a capacity of 20 gallons is requisite. A Henze capacity of 28 to 30 gal-

TABLE FOR ESTIMATING THE NECESSARY VOLUME OF THE HENZE APPARATUS, USING AS BASIS THE QUANTITY OF POTATOES REQUISITE FOR A MASHING CAPACITY OF 25 GALLONS.

Starch Content of the Potatoes	Necessary quantity, in pounds, of potatoes for each 25 gallons of mashing capacity to obtain a mash of 24° by saccharometer		Starch content of the potatoes	Necessary capacity, in gallons, of Henze apparatus for each 25 gallons of mashing capacity.	
Per cent.	Without vat cooling and removal of husks	With vat cooling and removal of husks	Per cent.	Without vat cooling and removal of husks	With vat cooling and removal of husks.
16	47.6	51.0	16	41.8	44.8
18	42.3	45.3	18	37.2	39.8
20	38.1	40.7	20	33.5	36.8
22	34.6	37.0	22	30.4	32.6
24	31.7	34.0	24	27.9	29.9

lons, or 25 gallons of mashing capacity, are necessary for mashes of 20° by the saccharometer, while a capacity up to 42 gallons is requisite for concentrated mashes of 24° to 26°, where the mashing capacity is more efficiently utilized through the removal of husks and the diminution of the vacant space above the wort by means of movable vat cooling.

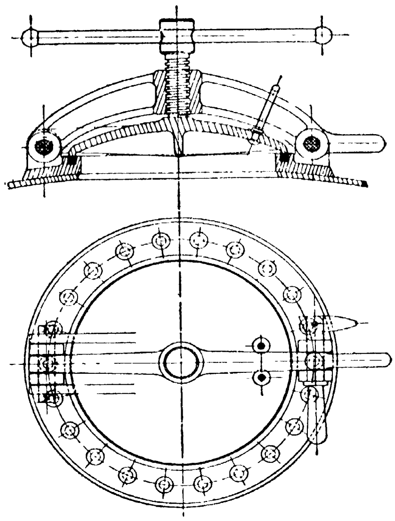

Fig. 18.—Modern Type of Henze Apparatus Closure.

The Henze steamer is not free from the danger of explosion due to the high pressure, and it comes under legal classification with steam drums and similar devices with regard to its arrangement and operation, and accordingly, it must be periodically examined by qualified experts. An ever-present danger in this apparatus is that due to rust formed by water dripping from valves and by the condensing steam. This rust frequently penetrates deeply into the metal, and may cause a weakening to which can subsequently be ascribed a disastrous explosion. Sometimes the apparatus is incased in non-conducting material to prevent loss of heat, and while this may be of value in the saving of fuel, it renders the surface of the apparatus difficult to inspect, and it readily collects moisture which may cause rusting. A moist covering is not only a good conductor of heat, but it is furthermore a direct consumer of heat, as the water it absorbs must be evaporated by the steam introduced into the apparatus. With regard to the safety of operation, the upper manhole cover or closing device of the apparatus was for long a questionable point. This is, however, no longer the case, as perfected closures have been devised which

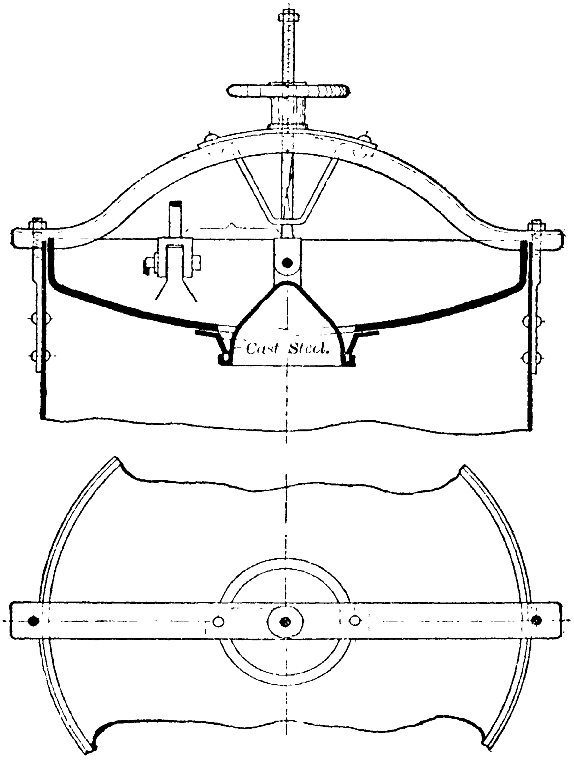

FIG. 19.—SAFETY MANHOLE COVER OF MODERN HENZE STEAMER.

eliminate this source of danger. An efficient construction is that illustrated in Fig. 18, which is the closure designed by A. Wagner. The cover is constructed entirely of cast steel, and has a diameter of opening of 16 inches.

A new German design is that illustrated in Fig. 19. It differs from the usual constructions in that the closure, as well as the entire upper wall, is arched inwardly. This construction not only eliminates losses of material in charging the steamer, but also effects a perfect closure, for the locking cone, which, as shown in the engraving, is formed of cast steel, is forced against the lid by means of the pressure within the Henze apparatus. This design practially renders impossible an explosion at the manhole closure.

4.—The Devices Used With the Henze Steamer.

A. The Exhauster.

The steamed mass in the Henze apparatus is forced into the preparatory mash vat or fore-mashing vat by the blowing-out operation, and as it is at high temperature, it must be cooled before it comes into contact with the malt, for otherwise the diastase of the latter would be destroyed. In the older forms of the Henze steamer it was necessary to blow out very slowly, at the same time stirring the mash in the preparatory mash vat energetically, in order to avoid a rise in temperature to the point where the destruction of the diastase began. However, this purpose was not fully accomplished, as at and around the point where the blown-out mass came into contact with the mash, overheating and consequent destruction of the diastase could not be avoided. As a result of this, the introduction of the Henze apparatus necessitated the use of greater quantities of malt. In this connection the introduction of the steam jet exhauster, first constructed by Avenarius Brothers of Berlin, was an important forward step. The blow-out pipe of the steamer is located at a point 3 to 4½ feet above the preparatory mash vat in a funnel. Above the blow-out pipe, which is pointed downward, is located the steam jet exhauster. The action of this device is based upon the principle that a steam jet conducted through a narrow pipe, on entering a wider pipe carries along air with it from the surrounding space, whereby a rarefaction is formed into which air is con-

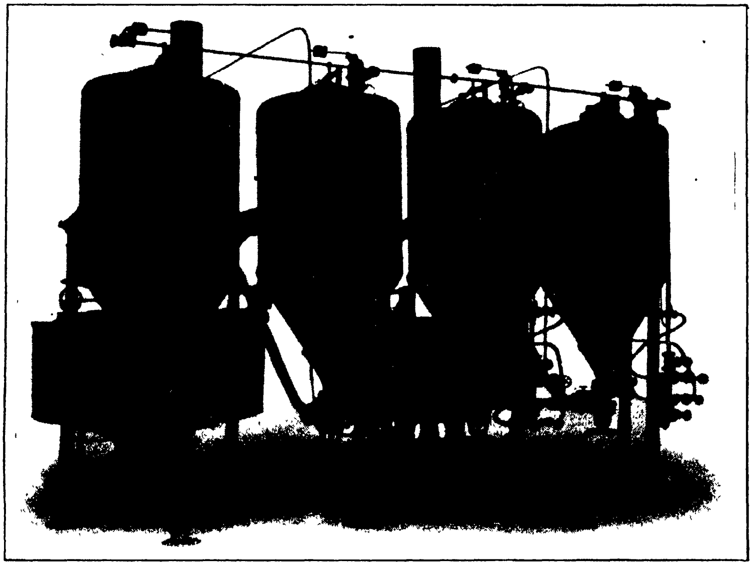

FIG. 20.—REAR VIEW OF A BATTERY OF HENZE STEAMERS IN A MODERN DISTILLERY.

stantly drawn. The exhauster draws a strong current of air through the funnel counter to the potato mass in the blow-out pipe, and thereby effects a thorough cooling and insures the success of the operation. The efficiency of the exhauster increases with the height at which it is placed above the preparatory mash vat, as the steamed mass can thus fall farther through the comparatively cold air. However, when the exhauster is placed 6 feet above the vat, the funnel pipe soon becomes incrusted with a thick layer of the steamed mass, from which lumps from time to time fall into the vat. These dissolve with difficulty. It is not easy to clean the incrusted funnel pipe, and the operation consumes considerable time. Therefore the exhauster is generally placed about 14 inches above the mash vat, and the mouth of the funnel pipe is given such dimensions that the steamed mass in passing through does not touch its sides.

For many years past, probably no Henze apparatus has been constructed without this arrangement of blow-out pipe, funnel and steam jet exhauster; but lately there has been a tendency to abandon the exhauster, and this is doubtless due to the recent advances in the construction of the apparatus. It must be admitted that the device is neither clean nor easily cleaned; organisms injurious to fermentation easily arise in the potato mass clinging to the sides of the funnel, and these later enter the mash and there they can no longer be destroyed. Furthermore, it sometimes happens that the blown-out mass solidifies to a horny paste while passing through the blow-out pipe and funnel, and this paste is dissolved with great difficulty in the preparatory mash vat. The exhauster was indispensable as long as the stirring device of the foremashing vat was unperfected and the possibility of local overheating remained. However, with the perfected and powerful mashing apparatus of to-day, together with effective water cooling in the preparatory vat, the danger of overheating is no longer so great, and thus a good distribution of the potato mass is effected in the newer apparatus, thereby avoiding the aggregation of the masses in the preparatory mash vat. In the modern apparatus the funnel and the steam jet exhauster are primarily used for the still necessary removal of the steam. Johann Hampel of Dresden, with his fore-mashing vat, proved to be a pioneer in the methods of construction based upon this consideration. It is to be noted that cooling by means of the exhauster yields mashes of greater concentration; in cooling with water more steam is condensed in the mashing vat and the mash is thinner.

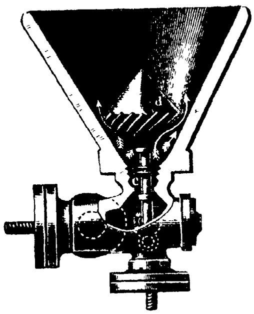

FIG. 21.—SCHEIBNER'S COMMINUTING VALVE.

B. The Blow-out Devices of the Henze Steamer.

The softened potato mass is broken up by being blown against the sharp cutting and tearing edges of the valve, the high pressure exerting itself explosively in the mass. In the first type of Henze apparatus an ordinary cock with a round opening was utilized, but it was soon found that the breaking up was incomplete with this form, and so the round opening was discarded for a sharp-edged slot. After this the cock arrangement was abandoned entirely and valves were introduced which were provided with sharp edges and corners. The first Avenarius valve must be considered the pattern for this type of valve. Other apparatus was subsequently designed which had a still greater cutting and tearing action. Among the latter the Scheibner comminuting valve, illustrated in Fig. 21, was the earliest.

With healthy potatoes these devices effect their purpose excellently; but it has been found necessary to provide special comminuting appliances in the blow-out pipe or valve in addition to the regular sharp-edged valve opening, for diseased potatoes, and above all, for working corn and other grains which are softened with greater difficulty and are disintegrated less completely than potatoes, in the Henze apparatus. The Bartel blow-out pipe may be mentioned as an example of these devices. The appliance, as shown in Fig. 22, is mounted at a chamber secured to the steamer and is separated from this chamber by means of a grating *c*, for the purpose of retaining stones and other foreign bodies. The blow-out pipe proper is provided with a number of studs or projections *g*, arranged in spirals and usually twenty-seven in number. The mash forced through the pipe is thrown powerfully against these sharp-edged studs and is thereby finely comminuted.

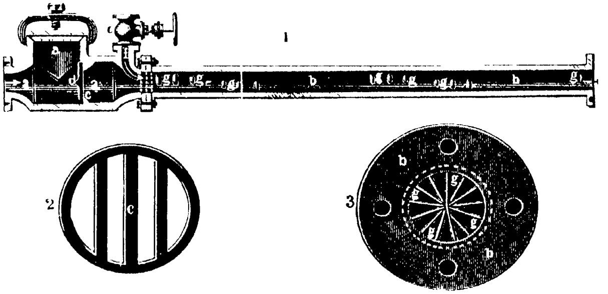

Fig. 22.—The Bartel Blow-Out Pipe for Henze Apparatus.

It may be said that if good raw materials are used and these are steamed properly and with due attention to all the affecting conditions, there is little necessity for special blowing-out devices if the ordinary valve is properly constructed with effective cutting edges. These special appliances, however, will be found of great value if the raw substance is poor or if the material worked is corn or other grain. It has been found good practice to place a grating in the blow-out pipe which will hold back stones and other large impurities and is also useful as an aid in the comminution of the steamed mass. However, between the grating and the valve there must be provided a steam cock and a hand-opening large enough to permit the removal of obstructions due to the collecting of impurities. In Fig. 23 is illustrated a Ger-

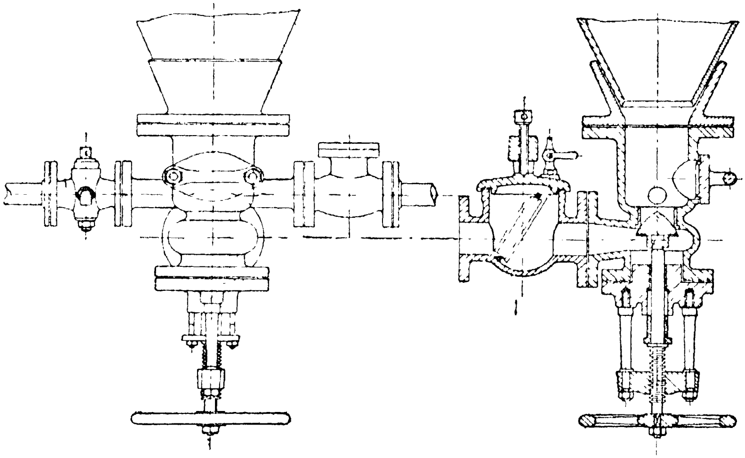

FIG. 23.—BLOW-OUT VALVE WITH REMOVABLE GRATING, CONSTRUCTED BY A. WAGENER, GERMANY

man type of blow-out valve with a removable grating, constructed by A. Wagener.

C. Mash Mills.

To assist in the complete comminution of the steamed mass, mash mills have been installed in the preparatory mash vats in certain types of construction. For this purpose the pulper of paper manufacture was first used by Venuleth and Ellenberger, while Victor Lwowski provided a centrifugal mash mill at the lowest point of the preparatory mash vat. These devices are no longer available with modern methods of operation, as their capacities in working concentrated mashes are unequal to the demands placed upon them.

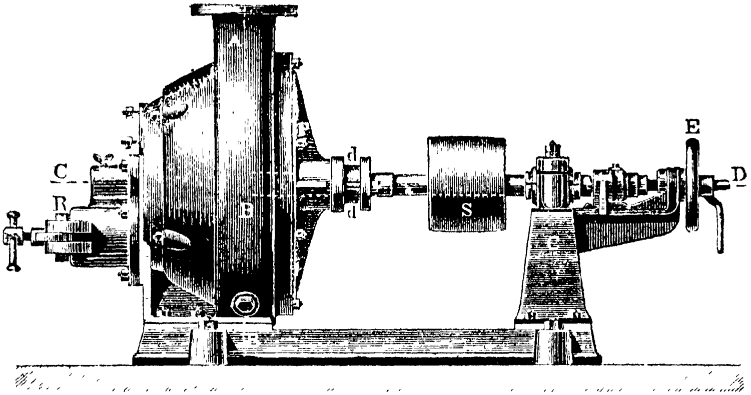

FIG. 21.—THE BOHM MASH MILL.

The mash mill which still enjoys the widest utilization is that of Bohm which, unlike that of Lwowski, is placed not in but outside of the fore-mashing vat. It draws the mash from the lowest part of the vat and returns it to the upper. It can be recommended as an aid to the operation of poor mashing apparatus only. As the steaming operation to-day is a very complete one, and as inefficient apparatus should no longer exist, these mills are seldom used in potato distilleries, though less infrequently in plants utilizing grain. Fig. 24 represents Bohm's mash mill.

II.—STEAMING CORN, GRAIN, AND OTHER RAW MATERIALS.

While the natural moisture of potatoes is quite sufficient for the disintegration of the starch which they contain, farinaceous grain like corn and other cereals must be provided with additional water during steaming in order to supply the necessary moisture for the gelatinization and dissolving of their starch, as these raw materials contain about 60 per cent of starch to but 13 to 15 per cent of water. The addition of the water presents one of the difficult features of the working of corn and other starchy grains. We shall see that special considerations must be taken into account in this regard.

A. Working Corn by the Old Method Without the Application of Pressure.

Corn can be worked without high pressure when it is in a very finely divided or crushed condition only. It is placed with the necessary water in the preparatory mash vat or in a special corn-cooking vat provided with a stirring device. About 40 to 45 gallons of water are necessary for each 100 pounds of corn. The crushed corn is slowly poured into the requisite water warmed to 130° or 140° F., with constant movement of the stirring device, to avert the formation of lumps. After this, steam is introduced into the mass, which is constantly stirred, so that the temperature rises to 194° to 203° F. It has been found useful to add about 1 per cent of crushed malt to the water before the bulk of the grain is introduced, to give a less tenacious mass. A large part of the gelatinized starch becomes more fluid, if the heating is carefully executed, because of the added malt; sugar, dextrin, and other combinations result. By this means a mobile mass, not easily aggregated, is obtained and the cooling of this mass can be effected rapidly and cheaply. The stirring apparatus is kept in constant operation and thus the mass becomes steeped through and through shortly after the grain is poured into the water. When the mass becomes steeped it diffuses a peculiar aromatic odor. The softened grain is cooled by the addition of water or preferably by means of suitable cooling appliances. After the cooling, the malt, which is doughed-in with 2½ times the quantity of cold water, may be added, the mixture being again thoroughly stirred. After this the vat is covered and the mass is allowed to stand the proper length of time for saccharization.

It is advisable to begin the cooling after the mass has stood at the cooking temperature for an hour or an hour and a half. The temperature is lowered to the proper point for mashing and the malt for this purpose is then added. The quantity of malt added for the sugar formation should be at least 7.5 per cent of the whole, though for active after-fermentation the use of larger quantities of malt is recommended. In Belgium, where kiln-dried malt is usually employed, 10 per cent and sometimes 15 per cent of this variety of malt are used.

The yield with this method of operation depends largely upon the degree of comminution of the grain. If the grain is not finely divided it is seldom possible to obtain more than 3 to 3.2 gallons of alcohol per hundredweight, with very finely comminuted corn 3.6 to 3.7 gallons may be produced. The theoretically possible yield cannot be obtained because the corn is incompletely disintegrated.

Corn can be worked with sulphurous acid with better results. This effects a softening of the inter-cellular substance and of the cell walls of the corn grains so that in the subsequent cooking a more complete gelatinization takes place; furthermore, the diastase can attack the starch with greater ease because the cell walls give less resistance. This action of the sulphurous acid, in general, may be compared to the dissolving of the inter-cellular substance and the cell walls in the malting process, for there is no difficulty in rendering the starch of a thoroughly dissolved malt available through moderate temperatures, for the action of the diastase. The sulphurous acid is used either as free acid in a watery solution, or in the form of one of its salts. The sulphurous acid of commerce which contains about 6 per cent of acid should be used in the proportions of 0.45 to 0.55 gallon for every 100 pounds of corn, with sufficient water to cover the corn to the depth of an inch or so. During the steeping the temperature must be maintained at about 120° F. The corn rapidly and with avidity absorbs the diluted acid, so that its starch can afterward easily be dissolved when the mashing is carried out at a temperature of from 158° to 167° F. For the same purpose bisulphate of soda is also used; about 2 parts by weight of this should be added to each 100 parts of corn. Here, too, the steeping period at a temperature of 122° F. lasts about eighteen hours. In using bisulphate of soda so much sulphuric acid or hydrochloric acid must be added that sulphurous acid is finally set free from the salt. This released acid while being formed, energetically acts upon the cell walls to dissolve the same. Through this use of free sulphurous acid, or of sulphite of soda, the yield from the corn can be increased to 3.7 or 3.8 gallons per hundredweight of corn; but the alcohol produced is liable to contain free sulphurous acid, and is thus made unavailable for many purposes.

By the treatment with sulphurous acid the corn acquires a yellow color throughout and is thoroughly steeped. The soft mass, after being placed in iron vats and diluted to a liquid pulp, is heated by the introduction of steam to 185° to 195° F. The mass in each vat is kept in constant motion by a mechanical stirrer, the mash being allowed to stand in this heated condition for one or two hours, during which the swelling of the starch is completed. The necessary quantity of green malt, finely crushed and doughed-in with cold water, can be added during this "digesting" period.

Finally, there is still another method of utilizing sulphurous acid. In this process the corn, uncrushed, is steeped in an acid solution which contains 2.9 to 3.2 ounces of acid for each 100 pounds of corn. After twelve hours the liquid is drawn off. The grains of corn, which can be crushed between the fingers like green malt, are allowed to dry, and it requires but a very slight pressure in steaming to convert the corn to a fluid and completely disintegrated mass.

B. Working Corn Under High Pressure.

All artificial refinements in the working of corn have become unnecessary since it has been discovered that the grains can be completely disintegrated under high pressure in the Henze steamer. In this method, which has been developed largely through the researches of Delbrück and his associates, almost the entire starch mass undergoes disintegration. It is to-day almost universally employed, though the process varies somewhat in its details in individual distilleries. The corn is steamed either in the whole grain or partly crushed. Sometimes it is also worked as grist in a finely-divided condition.

1. Working the Corn in the Whole Grain.

In working corn in an unground state the following conditions should be observed:

1. It is necessary to provide the corn with sufficient water to steep the starch completely. Experience has shown that each 100 pounds of corn should preferably be worked with 16 to 20 gallons of water in the Henze apparatus; however, it is considered of advantage by certain experts to limit the water as far as possible. The requisite quantity of water is first placed in the steamer, the lower steam inlet is opened, and steam is introduced until the water begins to boil, whereupon the corn is slowly poured into the apparatus. The latter must possess a capacity of 40 to 45 gallons for each 100 pounds of corn. While it is true that 100 pounds of corn with the necessary quantity of water require a capacity of but 30 to 35 gallons, it is also necessary to allow about a third of this space for the swelling of the grain, for the accession of condensed water which naturally cannot be drained off, as well as for a certain space requisite in cooking.

2. The distribution of steam in the Henze apparatus should be as thorough as possible. With the older forms of steamer, simple steam inlets are not sufficiently effective, and special steam distributors are necessary Fig. 25 shows an excellent type of this device. No special steam-distributing apparatus is necessary in the modern, conical form of steamer.

3. In working corn it should be a rule to maintain the grain in energetic motion from the beginning to the end of the operation, so that each individual grain of corn comes into contact with the necessary quantities of water and

steam. To accomplish this, instead of placing first the corn and then the water in the apparatus, the operation is reversed, and the water is first introduced and brought to the boiling point, whereupon the corn is slowly poured into the apparatus. After the introduction of the raw material, steam is permitted to flow through the device, the manhole being kept open for a full hour until the grains are entirely softened. However, as water and corn are sometimes accidentally thrown out through the open manhole, it is of advantage to close the latter and to open the cock of the tube located at the upper part of the apparatus, so that steam may escape therethrough during the remainder of the operation. The cock should be opened wide enough to permit the steam to escape so rapidly that no increase of pressure results in the apparatus.

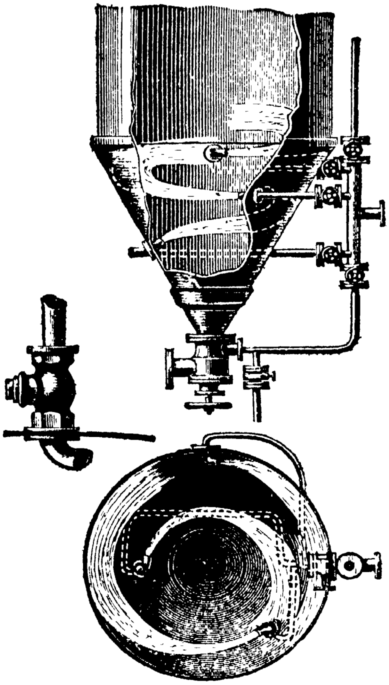

FIG. 25.—THE BILSDORF STEAM DISTRIBUTOR.

After one hour this cock is partly closed, but only so far that a fairly lively flow of steam still escapes through it, while at the same time steam is introduced through the inlet at the lower part of the apparatus, so that the mass is in constant motion, the pressure increasing to 2 to 2½ atmospheres. The steam at this pressure is allowed to act upon the corn for about an hour, with constant escape of steam and with constant internal movement of the mass. Not until the second hour has elapsed is the upper steam cock entirely closed, and after this for one-quarter to one-half hour the pressure is maintained at 3 to 4 atmospheres, care being taken to insure that the safety valve, which is set for this pressure, constantly blows off. By thus permitting the safety valve to blow off the steaming mass is kept in thorough agitation, and this is an essential for energetic boiling and complete disintegration. The steamed mass is then blown out at the maximum pressure through valves provided with sharp cutting and tearing edges.

4. It is sometimes advisable to steam the corn to a slight degree on the day before the working proper, and to allow it to stand over night, in order to decrease the working period. In this preliminary operation, the pressure should not exceed 2 atmospheres. Under these circumstances it is sufficient, on the following morning, to bring the pressure rapidly to 3 or 4 atmospheres and maintain it at this point for a short time. The mass may then be blown out at once. If it is desired to steep the mass on the preceding evening in hot water in the Henze apparatus, care should be taken that the temperature does not fall below 122° F.—the souring or acid-forming temperature.

5. In working corn it is unnecessary to provide a specially constructed blow-out pipe. The main feature of the operation is the blowing out of the apparatus under the maximum pressure. In blowing out slowly at low pressure the mass moves sluggishly through the open valve, and thus forms large aggregated lumps which are not properly comminuted. To increase the force of the blowing out of the mass, the Henze apparatus may be provided with a

steam cock to permit frequent and easy cleansing of the valve.

The steam-distributing device should be so located that the grains of corn are forced upward from the cone to avoid their lodging in the point of the apparatus. It is not advisable to permit the pressure to exceed 4 atmospheres, for at higher pressures the sugar in the corn and the diastase undergo changes which give the mash a brown coloration and by which starch is wasted. These are not the only disadvantages caused by too great pressure, for if the latter is continued fatty acids are formed from the fat in the corn, and these acids are decomposed at high temperature to form products which give an unpleasant odor to the resulting alcohol.

2. *The Working of Grist.*

While it is conceded that working the corn in the entire grain is a better process than working the material in a finely-divided condition under low pressure, it is nevertheless recognized that the first method has certain disadvantages. These are, principally, that the operation is of long duration, that it requires high pressure, and in consequence, is expensive. Under high pressure carbohydrates capable of fermentation are liberated, and it is even possible that decomposition products result which are directly injurious to fermentation. Furthermore, the alcohol produced by this method often leaves much to be desired with regard to fineness and purity. It is sometimes also claimed that corn steamed under high pressure requires a larger space above the wort than if it is worked as grist at low pressure. And finally, it is said that the wash resulting from the high-pressure method is less suitable for fodder and possesses less nourishment than that produced by the second method.

For these reasons a more suitable method of working has been sought by many investigators, and to find this it has been necessary to revert to working ground corn under low pressure. It was shown by the investigations of Delbrück that in this method of working it is necessary, above all, to prevent the grist, which is placed in hot water, from aggregating and forming lumps. This can be accomplished by permitting the grist to run into the boiling water in a very fine stream, with constant stirring of the mass by means of an ordinary wooden oar or stirrer. It is of greater advantage to provide the Henze apparatus with a powerful stirring device, which, at the beginning of the operation, should be constantly operated. After this the mass is cooked for an hour, as usual, without pressure; it is then rapidly raised to the maximum pressure of 3 atmospheres, and blown out in the customary manner.

In detail the operation is conducted as follows:

For each 100 pounds of grist 18 to 23 gallons of water, at a temperature of 131° to 140° F., are introduced into the steamer. The stirring apparatus is set in motion, and the grist is slowly poured into the apparatus. After nearly half of the grist has been introduced, about 1 to 1½ per cent of ground malt or crushed green malt is thrown into the apparatus, and the remaining half of the grist is then added. The contents of the apparatus are now heated to the cooking temperature in about 20 minutes. The steamer is closed, and the pressure is gradually raised, so than in 20 minutes it is 1 atmosphere, in 40 minutes 2 atmospheres, and in 1 hour 3 atmospheres. The mass is allowed to stand at the maximum pressure for about 10 minutes, and is then blown out. If the grist is less finely ground, the steaming process should last somewhat longer. According to Foth, 4.5 to 4.6 gallons per 100 pounds of corn are obtained with this method of operation in Belgium, where 15 per cent of kiln-dried malt is generally employed.

In this way it is possible to obtain thoroughly disintegrated mashes from corn in the unbroken grain, as well as from ground corn, by means of the Henze apparatus. But the attending disadvantage that very concentrated mashes cannot be produced, becomes an important factor in countries where taxation on the basis of the mashing capacity obtains. Under such circumstances, when it is necessary to use concentrated mashes, it is hardly advisable to use the Henze apparatus for working corn. According to Wittelshöfer, horizontal steamers are better suited for working grist. Apparatus of this character is largely used in Belgian distilleries. It is less difficult to provide horizontal steamers with powerful stirring devices such as that of the Hollefreund apparatus. With the agitation produced in such apparatus the quantity of water to be added can be so limited that it is unnecessary to use more than 12 gallons of water per 100 pounds of corn, while in the Henze steamer 14 gallons of water on an average are necessary for the same quantity of grain. Furthermore, in case of interruption or when repairing or cleansing is necessary, a horizontal steamer is more easily gotten at and can be controlled with less difficulty. In devices of this kind, the grist is first steamed slowly with constant stirring; the pressure is then rapidly increased to 2 or 3 atmospheres, and is maintained at this point for a short time only, so that the entire operation from the closing of the steamer to the end, does not last longer than an hour. In this apparatus, thorough steam distribution and a powerful stirring device are, of course, necessary. The horizontal steamer is to be recommended for use in distilleries where the boilers are not designed for the high pressure necessary when steaming corn in the unbroken grain.

C. Working Corn with Strong Mineral Acids.

As is well known, starch can be converted into fermentable sugar by cooking with strong acids, such as sulphuric or hydrochloric acid. In warm countries, where the preparation of malt presents difficulties, this method of working the grain has been introduced successfully. For the purposes of this operation strong horizontal boilers of sheet copper are employed. The corn is ground, and the finer the resulting meal, the shorter will be the time required for the action of the acid. For each 100 parts by weight of meal or grist 400 parts of water are placed in the boiler, and 7 to 8 parts of sulphuric acid of 10° to 15° Bé. are added if the corn is finely ground, or 8 to 10 parts of acid if the comminution is less thorough. The mass is steamed for 6 or 8 hours at a pressure of 2 to 3 atmospheres, with constant movement of a powerful stirring apparatus; the mash which has acquired a brown coloration is cooled to the fermenting temperature, and the free acid is then carefully neutralized by the addition of milk of lime or whiting, so that the mash still retains a weak but distinct acid reaction. The yield with this method is not as low as might be expected, for it is possible to obtain 3.2 to 3.8 gallons of alcohol per hundredweight of corn.

Of course, the spent wash from this operation is useless as fodder, for it contains large quantities of lime salts. To overcome this defect, however, the process has been modified by saccharizing the corn with hydrofluoric acid. The acid is neutralized with milk of lime and chalk so that it contains less than a gramme of acid per liter, and by means of filter presses is then separated into wort and cakes. The former enters into sound fermentation without yeast, and after the cakes have been leached again with water and pressed they form valuable fodder. According to a method used largely in France, 5 parts by weight of hydrochloric acid to 100 parts of corn are sufficient, and 3.4 gallons of alcohol and 7 to 8 pounds of compressed yeast can be obtained from each 100 pounds of corn.

After the mash has been placed in the fermenting vats, it is mixed with mash of the previous day's operation. As this is in full fermentation, it induces fermentation rapidly in the new mash, and the excited fermentation is complete in 2 to 2½ days.

D. Working Corn by Means of Compressed Air.

This is a process patented by Mandel, and experiments which have been made with it are claimed to have given satisfactory results. The color of the resulting mash was not brown, but nearly white, and this showed that practically no sugar had been lost by caramelization, and that the starch was more completely disintegrated than by other means. Empyreumatic products were found neither in the mash nor in the spent wash. In this process the raw material, eventually with the necessary added water, is heated or steamed to a temperature corresponding to the pressure of the atmosphere. It is then subjected, by means of compressed air, to a pressure of 4 to 5 atmospheres, and is then blown out. During the process, and while the raw material is being blown out, it is kept near the boiling temperature by the introduction of steam, or by heating the air during compression to about 230° F. The process has been modified so that the corn in a finely-crushed state is worked for 2 hours in a Henze apparatus, which is provided with a special device for distributing the steam under a pressure of 1 to 1½ atmospheres. Subsequently, the air pressure is introduced by means of a compression pump.

E. Working Malted Corn.

Through proper germination, the corn is so thoroughly disintegrated that the starch can be dissolved and saccharified, even at low temperatures, with comparative ease. Thus, if corn which is to be worked is permitted to germinate, and is crushed or preferably comminuted in centrifugal mills, and if then mashed with water at 153.5° to 158° F., practically the entire quantity of starch which it contains is dissolved. This method has at times been used in Hungarian corn distilleries, but with fair results only as compared with those in more modern processes. The method possesses the disadvantage that during the germination of the corn micro-organisms are produced which are injurious to fermentation, and furthermore, certain quantities of starch are consumed through respiration. Therefore, this method has been generally abandoned.

F. Working Mixtures of Potatoes and Corn.

In this method the corn and potatoes are separately disintegrated, generally in Henze steamers, though sometimes the potatoes are worked in a Hollefreund or Bohm apparatus, wherein the mass is rendered more fluid by the addition of malt. According to Delbrück, however, the raw materials may be worked together in a Henze steamer by steaming the corn for a certain period before the entire quantity of potatoes is introduced into the apparatus. Generally, the cone of the steamer is partially filled with potatoes, and upon this lower layer is placed the entire quantity of corn to be worked. Water is added at the rate of 8 or 9 gallons for each hundredweight of the grain. Steam is then introduced, and the rest of the potatoes is placed in the apparatus; after steaming for 1 to 1½ hours under a pressure of 4 atmospheres, the mass is blown out of the apparatus. If the potatoes are poor in starch, the grain should be steeped for 24 hours in hot water, having a temperature of at least 122° F.

G. Working Rye.

Rye is seldom used directly for the purposes of spirit manufacture. The whisky produced from rye is almost universally used as a beverage or medicine. Rye is often used in yeast factories because the nitrogen combinations which it contains are well suited for the nourishment of the yeast, and for this purpose rye rich in nitrogen is, naturally, preferably employed. The working of rye is similar in many respects to that of corn. It can be worked with or without high pressure in the entire grain, as well as in a comminuted state. Before it is used the grain must be very carefully cleansed, as an admixture of impurities not only decreases the proportion of useful material, but also introduces into the mash substances which may have an injurious effect upon the fermentation and which may seriously affect the purity of the product.

1. Working Crushed Rye at Ordinary Pressure According to the Method Employed in German Grain Whiskey Distilleries.

The rye is ground as finely as possible by means of mills, rolls, or other apparatus suitable for the purpose, and for several hours previously, preferably on the evening of the day before the mashing is to be carried out, it is impasted in the preparatory mash vat, or if the operation is plural, in specially-constructed vats. The steeping is effected in cold water, with the addition of 45 to 70 cubic centimeters of sulphuric acid of 66° Bé. to each 100 pounds of crushed grain, and with constant operation of the vat-stirring apparatus while the grain is being poured into the water. The stirring action must be strong enough to insure that the mass will be thoroughly worked throughout and will be uniformly steeped. By gelatinization with acid the albuminous substances are more thoroughly dissolved and decomposed, so that the mash loses its sticky character and becomes more mobile. In mashing, the gelatinized grain is gradually brought to the saccharizing temperature, 147° to 151° F., with constant working of the stirring apparatus. If corn is being mashed with the rye, the mass, to which has been added one-third of the total malt, is slowly brought to this temperature, and is maintained at that point for about half an hour. After this the rest of the malt is added with constant stirring, and after the accession of the malt the temperature is again brought to 149° F. After the mass has stood for another half hour, it is allowed to cool. Sometimes the total quantity of malt is added at the beginning of the operation, the mash being slowly brought to the saccharizing temperature, maintained at that point for three-quarters to one hour, and then cooled. Sometimes the operation is so conducted that one-sixth of the total quantity of malt is retained, and this part is not introduced into the mash until the cooling is in progress, that is, directly before the yeast is added. This late addition of a part of the malt has two advantages--foaming is avoided on the one hand, and on the other, a strong after-fermentation is induced. The latter is due to the unweakened state of the diastase and to the strong after-saccharizing efficacy of the malt. It should be mentioned, however, that this part of the malt is deprived of the disintegrating and purifying action of the higher mashing temperature, and thus the purity of the fermentation, as well as the yield, is injured, especially if the malt is of inferior quality. In every case the remainder of the malt must be as finely divided as possible, and if the mashing capacity is not taxed, it should be converted into malt milk, preferably with cold water.

2. Working Uncrushed Grain Under High Pressure.

In this method of working, the grain must first be completely cooked and then further disintegrated under high pressure, being finally blown out of the apparatus under the maximum pressure. About 20 to 23 gallons of water are placed in the Henze apparatus for each 100 pounds of rye. The water is brought to the boiling point, and the rye is then gradually added, while the water is kept in constant motion by means of introduced steam. First the mass is cooked with the steam valve open, and for a period of such length that the grains are fully softened. The pressure is now increased, the blow-out valve remaining open that the mass may continue to be agitated, and the steaming is continued under these conditions for an hour. Finally, with closed valve, the pressure is increased to 3 or 4 atmospheres, and is maintained at this point for about half an hour, whereupon the mass is blown out. With normal rye the method of working the grain uncrushed presents no difficulty; if, however, diseased, musty, or wet rye is of necessity employed, the method described above is not capable of utilization, even with high pressure, as the disintegration is unsatisfactory. Rye of this kind does not swell sufficiently during the cooking previous to the steaming, and the gelatinization of the starch is incomplete in consequence. According to the investigations of Delbrück, it would appear advisable to steep the rye, prior to the steaming, for a period of 12 hours, in water at a temperature of 122° F. in a wooden vessel provided with draining apparatus. Sulphuric acid should be added to the water in the proportions of 600 cubic centimeters of acid to each 100 gallons of water. On the completion of the period mentioned the acidulated water is allowed to drain off, and the rye is then placed in the Henze apparatus; after the proper quantity of water has been added, the mass is cooked with blowing safety valves, first for one hour, and then, under heavy pressure, for a second hour, after which it is blown out.

If there are difficulties in completely disintegrating the rye with the above methods, it is necessary to dry the grain before working. This is best accomplished in a kiln; in small plants where such is not available, the grain may be dried by spreading it out upon the boilers. With grain which has been thoroughly dried, the preparatory steeping can usually be neglected. Rye worked under high pressure yields inferior spirit.

3. *Steaming Mixtures of Rye and Potatoes.*

The working of rye and potatoes in mixtures is carried out in certain distilleries for the production of potable spirit, or in case of failure of the potato crops. The grain is naturally used in an unground state, and is almost always worked as described above, with preparatory steeping or preparatory drying. When this operation is completed, the rye and potatoes are together placed in the Henze apparatus, in such fashion that three to four hundredweight of potatoes are first placed in the lower part of the cone; above these, the rye is introduced, and upon the latter is poured the remainder of the potatoes. With this arrangement it is possible during the steaming to draw off the condensed and natural water without loss of rye. After the natural water is drawn off the steaming from below is continued for one to one and a half hours, and after the pressure has been gradually increased to 3 or 4 atmospheres, the mass is blown out.

The yield in the working of rye with kiln-dried malt customary in German grain distilleries is usually about 3.6 gallons of alcohol per 100 pounds of grist to which 15 per cent of malt has been added, that is, if the process of manufacture is properly conducted. In individual plants where greater quantities of malt and first-class grain are used with a view to improving the taste of the whisky, the yield may be 3.8 gallons or even more. In mashing corn with the rye, the yields are almost always higher than when rye and malt alone are used.

Mixtures of wheat or barley and potatoes can be successfully worked without crushing the grain if the latter is steeped for 12 hours in acidulated water, as described above. The mass is placed in the steamers similarly as for mixtures of potatoes and rye, and here too the lowest layer of potatoes is made to serve as a sieve through which the condensed and natural water drains from the layer of grain above.

PART VII.

THE MASHING PROCESS AND APPARATUS.

I.—THE METHODS OF OPERATION.

1.—The Purpose of Mashing.

BY steaming potatoes or grain the starch is gelatinized, or if high pressure is used, partially dissolved; but neither dissolved, nor, still less, merely gelatinized starch is capable of fermentation. Consequently, the starch must now undergo an operation whereby it is converted into sugar, a substance which is capable of direct fermentation. For this purpose malt is added, as the diastase of this substance converts the starch into sugar (maltose); this, however, is not directly capable of fermentation, but is transformed into fermentable sugar (glycose) through the enzyme of the yeast. The conversion of the starch into sugar is not as smooth a process as would appear, nor is the starch converted directly into sugar; intermediate products are first formed in every mash. These intermediate products are the dextrins, and these also are not directly fermentable. The conversion of the starch into sugar, the saccharization, is most nearly complete when the greatest possible quantity of sugar and the least possible quantity of dextrins are formed. To effect the best saccharization of the mash a number of considerations must be given attention.

2.—Principles to be Considered in Mashing.

a. In the action of diastase upon starch, the proportion of maltose formed increases with the dilution of the liquid in which the action is effected. It increases with the duration of the action, with the quantity of diastase used, and with the approach to the most favorable mashing temperature.

b. Among the substances formed by the conversion of the starch, maltose alone is directly fermentable by means of distilling yeast; the dextrins cannot be fermented by this agent. Under favorable circumstances, however, the latter too can be transformed into maltose during fermentation by an after effect of the diastase, and they also can then be fermented by the yeast. Hence it is of advantage, particularly in concentrated mashes, to induce thorough after-fermentation.

c. As, furthermore, the diastase must play an important part during fermentation, all those circumstances should be avoided in mashing which may in any way injure the diastase, for it can accomplish its purpose only if it emerges from the mashing process with full power and efficacy. In thick mashes the diastase must perform more work in its after action than in thin mashes, as in the former the proportion of maltose to dextrins is more unfavorable than in the attenuated mashes.

d. The most favorable temperature for the action of the diastase lies between 122° and 133.5° F.; at this temperature the greatest quantities of sugar are formed, and it would appear that this degree of heat would be the one best suited for mashing in practice. Experience, however, has shown that such is not the case. At these comparatively low temperatures, even with a thoroughly disintegrated malt, all the starch is not completely dissolved; this is accomplished far more satisfactorily at 146° F., and we are therefore compelled to choose a temperature which approaches the latter point. The low mashing temperature is impractical for another reason; in fermentation it is necessary not only to have a mash rich in sugar, but it must also be as free as possible from micro-organisms which could retard the fermentative action. These micro-organisms are not destroyed at temperatures ranging between 122° and 133° F., while at 146° F. they are nearly all so weakened that there is little danger of their injuring the fermentation.

e. Thus, there appears to be a complete paradox in the choice of a mashing temperature. The temperature most favorable for sugar formation lies between 122° and 133° F., but this cannot be chosen if we give due consideration to the question of the disintegration of the malt starch as well as to the destruction of inimical micro-organisms; we are forced by these reasons to choose a higher temperature. at which, on the one hand, the sugar formation is a poorer one, and on the other hand the necessary after-action of the diastase during the fermentation is retarded.

f. Fortunately, a compromise for these paradoxical requirements has been found in that the diastase is able to resist high temperatures much more successfully in liquids rich in sugar, than in watery, dilute solutions. Delbrück, together with Pätzold, has shown that diastase in solutions rich in sugar can withstand temperatures as high as 149° to 154° F. without being substantially weakened, while in weak solutions its efficacy is greatly diminished at 146° F. As a rule, it is inadvisable to employ saccharizing temperatures above 140° or 146° F., and with the minimum quantity of malt, even these temperatures should not be used; circumstances may nevertheless arise in which it would appear imperative to increase the saccharizing temperature. Higher temperatures would seem particularly effective in working abnormal or objectionable raw material, insuring purity in the fermentation. In such cases it is absolutely necessary to have the rise in temperature as gradual as possible, so that the formation of sufficient sugar may take place before the temperature dangerous to the diastase is reached.

g. Diastase is most strongly active in solutions which are slightly acid; in liquids of the strongly acid character which mashes sometimes possess, especially during after-fermentation, the action of the diastase is severely retarded because of the activity sometimes evidenced by acid bacteria, and, in certain cases, it is even destroyed. Therefore, in all cases, care should be taken to produce a mash as free as possible from fungi, and to maintain the purity of the fermentation to the end. This can be accomplished by means only of painstaking cleanliness in operation, by the use of proper antiseptics, and through proper mashing.

3.—Mashing in Practice.

The determined quantity of malt for the saccharization of the mash is placed in the mash vat with just enough water to permit the formation of a thick pasty malt milk when the mass is thoroughly agitated by means of the vat stirring apparatus, and the potatoes or grain are blown out from the Henze apparatus into the vat when properly steamed. The stirring apparatus is kept in constant operation, while the mashing temperature is carefully observed at all times. To obtain rapid and thorough action of the diastase, the malt used should be crushed or finely divided in some other manner. The blowing out should be so regulated with the aid of the exhauster, or by the employment of proper water cooling, that the temperature of the mash during the operation does not exceed a maximum of 131° F. In this manner about five-sixths of the contents of the Henze apparatus is withdrawn, and at the favorable temperature obtaining, the greatest possible quantity of maltose is formed, while at the same time the sugar solution is so concentrated that at the end of the mashing period the temperature can be raised to 140° to 144° F. without injury to the diastase. The mash is now cooled while the stirring apparatus is kept in operation as strongly as possible; at the same time the remainder of the mass in the Henze apparatus is blown out into the preparatory mash vat, so that the desired final temperature is attained. At this high temperature the malt starch is dissolved and saccharized, while, simultaneously, the injurious micro-organisms are largely destroyed. In consequence the best possible mash, completely saccharized, quite free from fungi, and with well-preserved active diastase, is produced.

The mash is allowed to stand for a certain period at the saccharizing temperature. Formerly it was considered advisable to permit this period to last from one to one and a half hours; at the present time, as the blowing-out period is longer and as the saccharization has progressed largely during the blowing out, this period is considerably shortened. With a good quality of malt, proper efficiency of the mashing apparatus, and normal operation during steaming and mashing, the saccharizing period can often be decreased to 20 to 25 minutes without detracting from the success of the operation. In some distilleries saccharization is allowed to continue for an hour and longer, even to-day. The circumstances and the method of operation in the individual plants should be taken into consideration in choosing the duration of the saccharizing period. Mashing methods differ in the manner of adding the malt. Many distillers make it a principle to add the total malt to the mass in the preparatory mash vat as soon as possible, with the idea, properly enough, that the longer the malt in its totality exerts its saccharizing effect upon the mash, and the longer it is subjected to the purifying action of the mashing temperature, the completer will be the results of the mashing. Others prefer to add the malt gradually, in small quantities during the blowing out, to avoid as far as possible the danger of scalding the diastase. Others, again, prefer to divide the malt so that two-thirds of the total quantity is placed in the fore-mashing vat for saccharization, while the remaining one-third is added after the mash has cooled to about 86° F., that is, shortly before the yeast is added. The last method of introducing the malt is recommended by Hesse in order to decrease foaming fermentation. Which of these methods is to be preferred depends upon the character of the malt, the efficiency of the mashing apparatus, the other operations of the mashing, and in every case, upon the experience and knowledge of the distiller himself.

For working potatoes which, in saccharization, give tough thick mashes, and in which, as experience has shown, fermentation is poor, Bücheler recommends the following method: The contents of the Henze steamer are rapidly blown out into the fore-mashing vat, and the mash is liquefied by the addition of 1 per cent of malt at the original liquefying temperature of 167° F., for about twenty minutes; the mass is then cooled to 144.5° and the rest of the malt is added. By this accession the temperature is reduced to 135° or 137° F., a very favorable temperature for sugar formation. The mash is allowed to stand at this temperature long enough to insure a relatively high proportion of maltose to the dextrins. In this way easy and complete fermentation of the mass, which *per se* is a thin liquid, is effected. Starch of the best modern varieties is, according to Bücheler, easier to saccharify than the older kinds, and it yields a relative proportion of maltose to dextrins of 4:1, and under certain circumstances, even of 7 or 8:1.

Among the advantages claimed for this method are the thinner character of the resulting mash, and the corresponding better utilization of the available space. From the accounts of practical distillers, however, the process does not lead to better results in practice, and in many cases the 1 per cent of malt added experimentally was not sufficient to liquefy the mash.

4.—Mashing Barley, Rye, Wheat, and Oats.

The grain is preferably ground to a fine grist, and if the material is very hard and horny, it is bolted. Crushed malt, which forms a fluffy mass with the glumes not too finely comminuted, is used. The preparation of the mash may be carried out in two ways—by mashing in two periods, or in one.

In the first method the requisite quantity of grist is doughed in with lukewarm water, previous to the actual mashing. This operation should be performed with care to insure that no lumps are formed, and should the latter, nevertheless, occur, they must be broken up by being forced through the meshes of a sieve. The mass should be thoroughly worked, and should not exceed the maximum temperature of 111° F. It should be constantly stirred and should be heated to the mashing temperature by the addition of boiling water. If the agitation of the mass by the stirrer is not energetic enough, it may be heated by the introduction of steam. The mash is then allowed to stand one hour for saccharification.

In mashing in a single period the malt and grist, with constant agitation, are gradually introduced into the entire quantity of water, heated to a temperature of 161.5° to 176° F. As it is difficult to keep the mass free from lumps, and because of the consequent losses in starch, this method is not recommended for general use. Furthermore, the high temperature impairs the efficacy of the diastase.

The mode of mashing in use in many English distilleries consists in the preparation of clear saccharine fluids, which are called worts. According to Brannt, the mash vats are provided with mechanical contrivances similar to those already described. The grain is finely comminuted between millstones, and the malt is crushed by means of rollers. The mashing is generally effected in

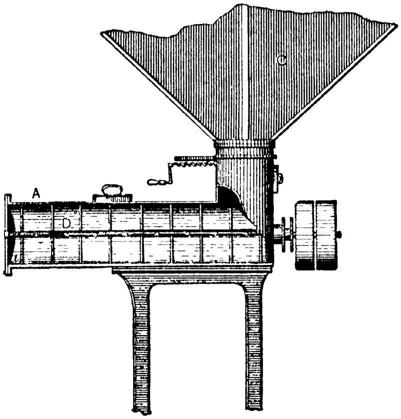

FIG. 26.—STEEL'S PREPARATORY MASHING MACHINE.

Steel's preparatory mashing machine, illustrated in Fig. 26. The machine is located over the actual mash vat, and consists of a copper cylinder *A*, closed at one end and open at *a*. Through the center of the cylinder passes the shaft *D*, provided with stirring arms; it is driven by a belt and pulley at the rate of 150 revolutions a minute. The grain is poured in through the funnel *C*, while the water runs in at the side. The mixture prepared in the cylinder flows into the mash vat itself, which is generally formed of cast-iron plates firmly bolted together. It is provided with a mechanical device which, by rotating horizontally and vertically, effectually agitates the whole of the liquor in the vat. The perforated false bottom of the vat allows the clear wort to percolate into the space between it and the true bottom, from which it is drawn off into the underbacks, large vessels placed beneath the mash vat wherein the worts are collected until pumped into the cooling vats. After the first wort is drawn off, a quantity of water at a temperature of 179.6° F.—as in the first mash—is poured over the mass in the mash vat. The second wort is drawn off in the same manner as the first. The whole of the saccharine and fermentable matters of the grist introduced into the mash vat is generally extracted in three, always in four mashings, but the manner of doing so differs according to the notions of the distiller. In some cases the first, second, and third mashings are evaporated until the mixture acquires a specific gravity of about 1.05, when it is thought to be ready for the fermenting vat, the fourth mash being reserved for extracting fresh quantities of grist.

The chief advantage of preparing clear worts is that all insoluble admixtures inimical to the purity of the product are excluded from the fermenting mash, the oils of a peculiar and always disagreeable odor being developed from the grains alone. A further advantage is that clear worts enable the distiller to make use of practically any kind of still, even one heated by an open fire, while thick mashes require stills of special construction. But, on the other hand, the yield of alcohol obtained from them is never so large as that from thick mashes, as it is scarcely possible, except with very complicated devices, to extract everything that becomes soluble during saccharization. Besides, all the starch of the grain is never entirely converted into soluble products, and, as has been proven by many experiments, a portion of the starch which remains undissolved becomes available afterwards during fermentation. Hence this portion is entirely lost as regards the yield of spirit, as well as a portion of the starch dissolved by the mashing process.

Under an accumulation of maltose the energetic action of the enzymes, which liquefy the starch and form the sugar, is in time entirely prevented. Thus, it is possible to convert all the starch into maltose in very dilute solutions only or by the use of large quantities of malt under special conditions. The mashing process of Porion is based upon the fact that if the sugar can be removed as it is formed, the starch can be converted into maltose in a comparatively short time. The method as elaborated by the inventor requires but 2 to 3 pounds of beer yeast, and at the most 5 pounds of malt for each 100 pounds of corn. The corn or other material, uncomminuted, is placed in a proper apparatus with three times the quantity of water and is brought to the boiling point. To soften it thoroughly the mass is allowed to stand for five or six hours at a temperature not under 203° F. By this steeping the starch is completely swelled, although the external appearance of the grain is not altered. The liquid is drawn off, and may be used for steeping fresh material, as it contains a certain amount of carbohydrates. The material is allowed to drain and cool in a shallow heap; it is then finely crushed, and is introduced into the fermenting vat, which has previously been charged with malt and yeast. The mass is thoroughly mixed, and left for simultaneous fermentation and sugar formation.

5.—Mashing Sacchariferous Raw Materials.

The best method of preparing mashes from sugar beets is one in which the juice is separated from the pulp. In fact, this is practically the only suitable method, because the beets contain a large percentage of mucilage and fiber substance, so that if crushed to a pulp they could be fermented in very dilute form only. Consequently, fermentation must be preceded by the extraction of the juice, and this can be effected successfully by pressure, maceration, or diffusion. The sugar of the sugar beet is not directly fermentable, as it is in the form of cane sugar, and must be first transformed by the ferment *invertin,* which is contained in the yeast, into a fermentable mixture of dextrose and levulose, known as *inverted sugar.* In preparing the mash the sugar beets, as well as the residual molasses from the manufacture of sugar, may be used directly. The molasses often contains, besides organic substances and inorganic salts, as much as 30 to 45 per cent of sugar. While improved methods of sugar manufacture have enabled us to recover a considerable proportion of this sugar, enough still remains to render the use of molasses for alcohol preparation profitable. In appearance the molasses is of a yellow to brown or brownish black color. In working molasses it is first diluted with water to 16 to 18 per cent of sugar concentration, though frequently it is worked in a still more concentrated state—about 15° Bé. Molasses because of its viscidity is diluted with water in mixing vats provided with powerful stirring appliances, or by means of a steam jet.

Raw sugar can, of course, be fermented directly in the usual manner, preferably after being dissolved in hot water and after dilution to the proper point. To accelerate the process of fermentation, which is normally a slow one, sulphuric acid may be added. The use of glucose and grape sugar for alcohol production presents certain difficulties, though the process is the same as for raw sugar and molasses. A solution of suitable concentration is prepared and is fermented at the proper temperature, after being acidulated with sulphuric acid. Cane-sugar molasses is generally worked in the same manner as cane sugar. If the molasses is alkaline, it is absolutely necessary to use sulphuric acid with the mash.

II.—THE APPARATUS USED IN MASHING.

The apparatus used in mashing can be divided into two classes: First, those which are not provided with water cooling, and which, naturally, require special devices for cooling the mash to the fermenting temperature; and, secondly, those which are provided with water cooling, and in which, consequently, not only the cooling of the mash to the saccharizing temperature, but also the cooling to the fermenting temperature after the termination of the saccharization, can be effected. In installing new apparatus, mashing vats provided with cooling apparatus should always be chosen; these are cheaper, and permit the operation to be carried out with the same rapidity as in those provided with separate coolers.

1.—Preparatory Mash Vats Without Water Cooling.

To this class belongs one of the oldest mashing devices used in connection with the Henze apparatus, namely, that of Venuleth and Ellenberger, Darmstadt, Germany. Ellenberger first employed the pulper of paper manufacture, for crushing and comminuting purposes in the mash vat. This construction at the present time, however, possesses an historical value only. The apparatus is no longer available with the methods employed to-day, as its capacity is unequal to the demands placed upon it in working extremely concentrated mashes.

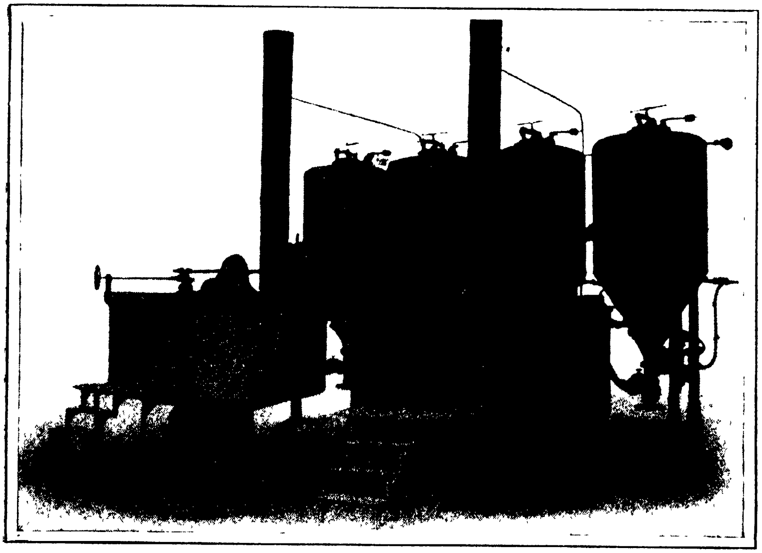

FIG. 27.—MASH VATS OF MODERN CONSTRUCTION.

The preparatory mash vat of Paucksch was one of the first of the type in which centrifugal action was employed; it was introduced in many breweries, and was set up in

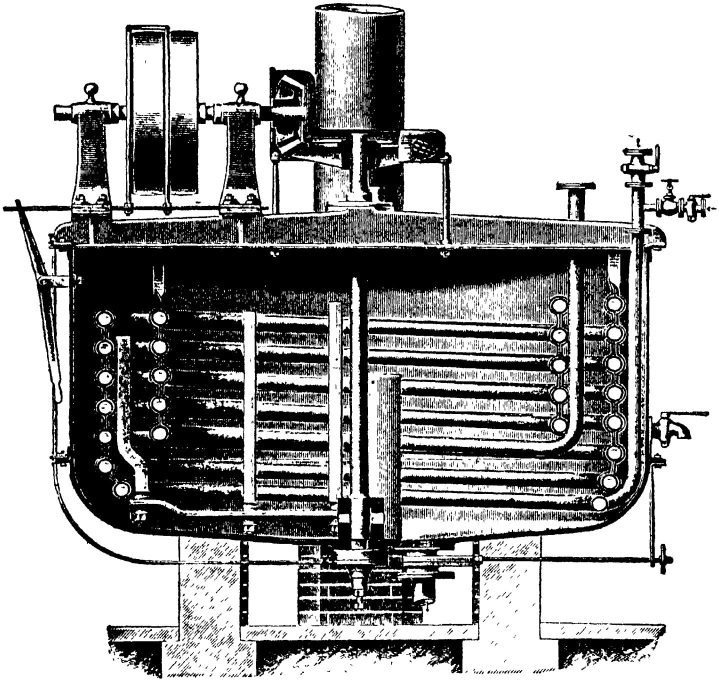

FIG. 28.—PAUCKSCH MASHING AND COOLING VAT WITH INVOLUTE STIRRER.

large plants in connection with batteries of Henze steamers. This device has also been replaced to-day by a different construction designed by the same firm. The older form possessed a bowl-like body with an upper, cylindrical part; upon the bottom, mounted on a rigid base plate, was a vaned wheel or flighter, actuated from underneath the device by means of a shaft. The wheel drew the mash from above and hurled it against the sides, thus effecting a powerful and uniform mashing action.

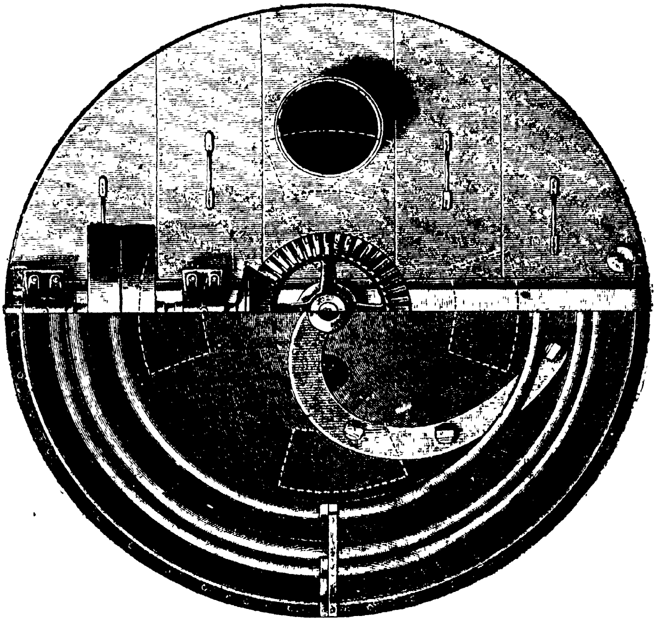

FIG. 29.—PLAN VIEW OF THE PAUCKSCH MASHING AND COOLING VAT.

2.—Water-Cooled Preparatory Mash Vats.

In the modern Paucksch vat, which is shown in Figs. 28 and 29, the flighter is replaced by an involute stirring member. The actuating device has been advantageously altered by the introduction of gear transmission, and, finally, the vat has been provided with an efficient cooling coil or worm. The apparatus can be recommended because of its excellent construction, good mashing action, rapid cooling, and easy cleansing. Mash vats similar to that of Paucksch's are constructed by A. Wagener, Cüstrin, Germany. Among the innovations which these show are copper cooling pipes, which can be taken apart, and arched bottoms. The diameter of the apparatus is two to three times its height. The driving shaft is located in special bearings, and is provided with conical gears having teeth of special construction. These vats can be recommended because of their excellent and strong construction and their proven high efficiency.

The modern systems are almost all provided with water cooling, and the examples below are given as typical of these constructions. In general, all the latest preparatory mash vats can be said to accomplish their purpose effectually. The manufacturer has been able to meet the requirements of the distiller in constructing these devices, and the efficiency of the apparatus is, on the whole, comparatively high. The following points should not be lost sight of in choosing a vat: The device should, first of all, possess a powerful mashing action, in order that a rapid and uniform mixing of the mashed raw material can be effected, with rapid equalization of the temperature in all parts of the mash, in the mashing vat; further, an efficient cooling system must be provided in the vat, and this should be so constructed that it can be taken apart without difficulty, that it may be cleaned internally and externally with great thoroughness. The cooling of the mash to the pitching temperature must be possible of accomplishment in three-quarters to one hour, and in this operation the consumption of cooling water at a temperature of 50° F. should not exceed two gallons per gallon of mash. Finally, the entire mashing apparatus must be so constructed that it can be cleaned throughout in the most thorough manner by scrubbing with the brush, in order to avoid boiling with water or steaming.

The mashing apparatus of Hampel, Dresden, illustrated in Fig. 30, was the first system which rendered the exhauster unnecessary, as it provided thorough and rapid distribution of the blown-out material, and effective cooling of the mash by energetic agitation. The blow-out appliance used with the Hampel apparatus is shown on a larger scale in Fig. 31. In this figure, *b* represents the blow-out pipe of the Henze apparatus. The mass passes through this into the chamber *c*, which flares outwardly at its lower part. In this chamber is located a cone *g g*, actuated by the shaft which drives the flighter *o*, Fig. 30. The cone works against the side of the chamber *c*, so that

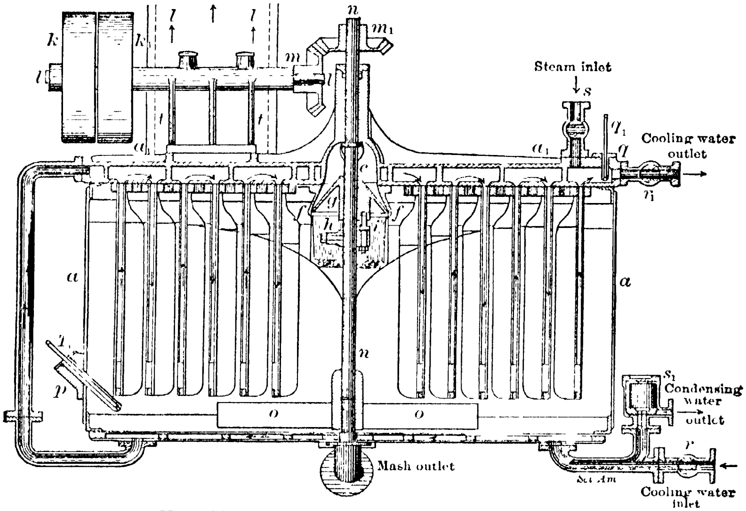

FIG. 30.—HAMPEL'S MASHING APPARATUS.

it can be closely adjusted at *f*. Thus, the mass is blown out into the preparatory mash vat through the narrow annular slot at *f* in the form of a thin bell-shaped stream. Here it is immediately incorporated in the rapidly-stirred mash without local overheating, and is at once thoroughly mixed with the latter. The Hampel vat is provided with a simple but very effective flighter *oo*, and a system of cooling pockets. The cooling water enters at the bottom of the vat, and passes upwardly through a pipe into a hollow cast-iron beam a_1, to which the cooling pockets are attached. The latter are usually constructed of copper, and have internal partitions, so that the water flows down one side of the cooling pocket and up the other, and thus passes from pocket to pocket until it escapes at r_1, from the hollow beam. The same principle is made use of in practically all the systems employing cooling pockets, but, as said before, it was first introduced in its perfected form by Hampel.

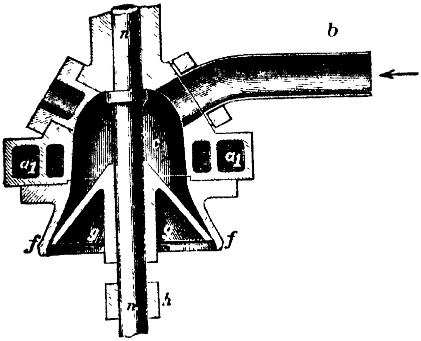

FIG. 31.—HAMPEL BLOW-OUT DEVICE FOR HENZE APPARATUS.

Entirely different from the apparatus described so far is that of Pampe, illustrated in Fig. 32. This consists of a closed, cylindrical fore-mashing vat, a vertical shaft passing through the center of the same, and a hollow column located within the vat. The last has a pear-shaped lower portion and a plate-like surface at its upper part, as is shown by the light broken lines in the engraving. The pear-shaped portion contains a pump of the centrifugal type; the upper part is provided with a rotary flighter. The pump draws up the mash, while the flighter hurls it powerfully against the walls of the vat, which is entirely closed; the mash then trickles down the sides interiorly and is cooled by surface sprinkling of the outer walls of the vat. Inefficient as this cooling would appear to be, at first glance, it is remarkably effective, and is attended with the great advantage that the cooling element is not covered up and is practically unbreakable. The rotary pump is driven at the rate of 160 to 180 revolutions per minute. The steamed mass is forced from the Henze apparatus upon a sheet-steel distributing disk, revolving about 350 times a minute, where it is somewhat cooled, and then passed in the usual manner into the apparatus. The Pampe mashing apparatus is, of course, provided with the jet exhauster. But this is not located in the blow-out arrangement and, consequently, cannot contaminate the mash by residual starch mass clinging to its sides.

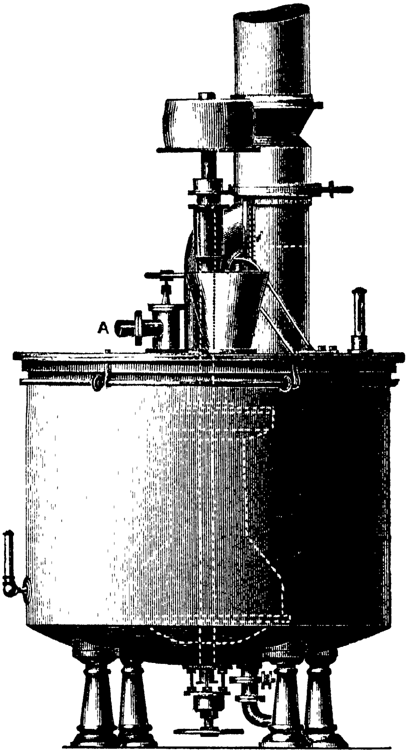

FIG. 32.—PAMPE MASHING APPARATUS.

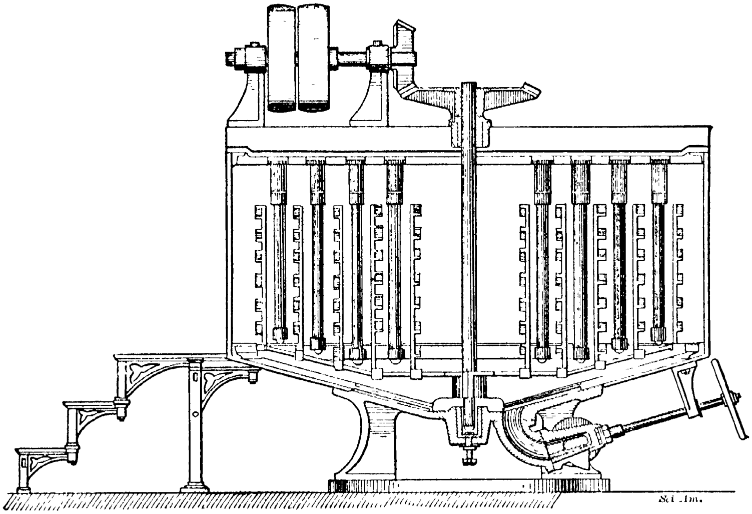

FIG. 33.—ECKERT SACCHARIZING AND COOLING VAT FOR CONCENTRATED MASHES.

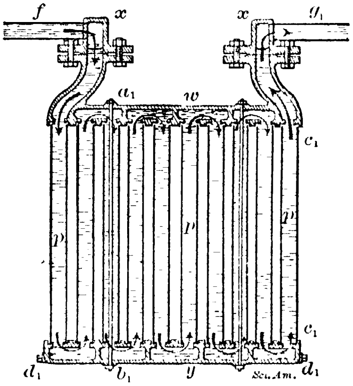

FIG. 34.—COOLING ELEMENT OF THE ECKERT MASHING VAT.

Every demand of the modern method of mashing is fully met in the preparatory mash vat constructed by the H. F. Eckert Company, of Berlin, which is shown in Figs. 33 and 34. This apparatus is designed particularly for concentrated mashes; it is of cylindrical form with a conical bottom projecting downward from the body. Within the body are a horizontal shaft and a rod-stirring device, which is driven by the shaft, and which works through the cooling system.

The latter comprises straight, brass tubes, and two cast-iron head and connecting pieces. The tubes pass through the heads and are joined together. They are secured to each other by these heads, which are held in place by screws. The cooling efficiency of this system is high, and as it is easily taken apart, it possesses the advantage that the cooling pipes can be internally cleansed without difficulty; the power consumption of the apparatus is comparatively small, notwithstanding that the mashing action at 110 to 120 revolutions per minute, is an excellent one.

The necessity for working extremely concentrated mashes, severely taxing, as it does, the stirring apparatus. is the reason for the very massive construction and the strong arrangement requisite in preparatory mash vats. An ordinary rotating mill is no longer sufficient, and with present methods, particularly powerful stirring apparatus must be provided. An apparatus capable of efficient operation with even the thickest mashes is that constructed by C. F. Bohm, Fredersdorf, Germany. This is shown in Fig. 35. In the construction of this type of apparatus, all those considerations which enter into the design of an efficient mash vat have been given proper attention. A most thorough working is effected by stirring arms mounted upon a vertical shaft; they extend almost to the wall of the vat. The arms travel between the straight tubes by means of which the device is cooled, and effectively stir the contents of the vat, even if the mash be of the most highly concentrated character. The agitation of the contents of the vat is assisted by the straight cooling pipes which prevent the mash from rotating with the moving stirring arms. Consequently, the temperature is practically uniform in all parts of the mass. As the stirring apparatus rotates comparatively slowly, it requires but little power to drive the mechanism. The bearings in the apparatus are of special construction. The cooling system, consisting of straight tubes, cools the mash rapidly to the desired temperature, and requires a comparatively small amount of water. The cooling elements can be cleaned with the greatest of ease, as the individual tubes can be freed from slime, dirt, etc., by a simple brushing out with a proper utensil. This is a decided advantage, as under these circumstances the cooling efficacy always remains uniform. The internal construction of the apparatus is such that there are no corners, projections, etc., which can interfere with easy and rapid cleansing. Another apparatus of Bohm, which is provided with a single cooling worm or coil, corresponds in its general features with the form described, and the concentrated mash stirring device with which it is provided is very effective, even at slow speed. An exhauster of practical form, pro-

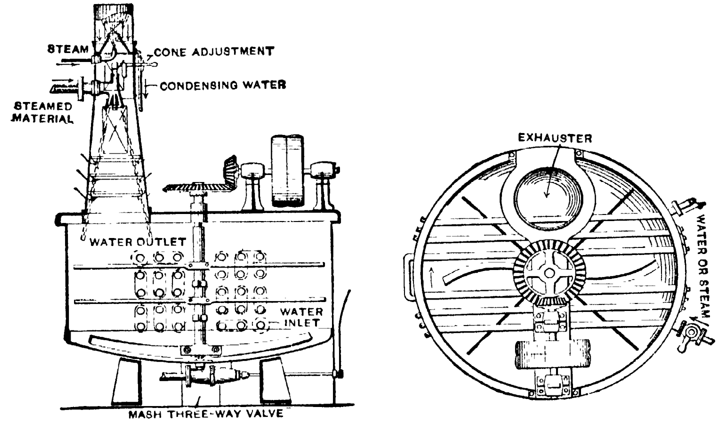

Fig. 35.—Elevation and Plan View of Bohm's Mashing Apparatus.

vided with a cone adjustable externally to avoid the choking up of the device, and a trap for the condensed water, are included in the apparatus. The further details can be easily understood from the illustration.

In addition to the types described above, the same firm builds a so-called tub vat. The arrangement of this vat, as exemplified in the model of 1902, is as follows: The upper portion is prismatic in form, but is rounded off at the lower part to constitute a half cylinder. This construction avoids corners and angles, and renders the cleansing of the device a simple matter. The agitation of the mash is effected by means of stirring vanes, which are mounted obliquely upon a massive horizontal, central shaft. The shaft is supported upon the bottom of the tub, and runs in stuffing boxes. It is driven by means of a belt and pulleys from the main transmission. The power consumption of this type of device is smaller than that of vats provided with centrifugal stirring apparatus. The tub of this form of apparatus with a mashing capacity of approximately 560 gallons is about 9 feet long, 5 feet wide, and 5 feet high, so that it requires comparatively little room.

In this construction, too, the use of straight cooling tubes is particularly effective. These are arranged in parallel pairs, at the longer, opposite sides of the vat, and pass through the bottom of the tub. They are joined together on the outside of the tub by means of external caps, which are designed to prevent leakage. This arrangement possesses the great advantage that the tubes can, from time to time, be cleaned without difficulty, after the caps have been removed, by means of a long wire brush. And it can no longer be doubted that with cleanliness in the cooling system, the efficiency remains undiminished and uniform. As the cooling tubes are, at the same time, connected with the steam supply, the mash in the preparatory mashing vat can be heated, if desired. Notwithstanding a comparatively low water consumption, the efficiency of the cooling system is high.

The limits of this treatise make it impossible to illustrate or describe further apparatus of this character, notwithstanding that many excellent and efficient devices are constructed by other firms and are extensively used. Besides the general considerations to be observed in choosing new apparatus, as described above, the efficiency of the device, as well as the room it requires, should be taken into account. The capacity of the mashing vat, not including the allowance for the cooling apparatus, should be about 140 gallons for each 100 gallons of fermenting vat capacity. The form of the mashing vat should correspond to that most suitable for the kind of stirring device employed. Centrifugal stirrers should be driven at the rate of at least 80 to 100 revolutions per minute. The cooling tubes, preferably of copper, should have a wall thickness of at least 3/16 inch. For each 100 gallons of mash about 1.1 square inches of cooling tube surface should be provided. Goslich recommends that the mashing vat be connected with the montejus, a device for raising or transporting liquids by steam pressure. A form of this device is illustrated in Fig. 36.

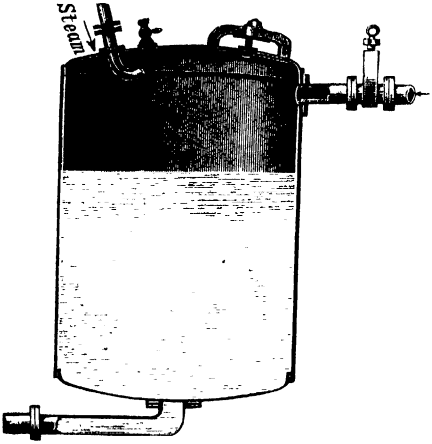

FIG. 36.—A MONTEJUS OF THE TYPE USUAL IN THE DISTILLERY.

III.—CLEARING THE MASH.

This operation is necessary in working with concentrated mashes only. These contain greater quantities of husks and spent grain than do attenuated mashes, for in preparing them greater quantities of raw material are used for the same mashing capacity than in the latter. Consequently, fermentation in concentrated mashes becomes inactive and incomplete, and the mashing space is encumbered with unproportionately large masses of spent grain. It would appear to be of advantage to remove all the husks and other insoluble constituents from the mash, and to ferment a wort, that is, a clear liquid. Experiments which have been made in this connection have, however, shown that the opposite is the case. It has been proven impossible to ferment completely wort from concentrated mashes. In a wort of this character part of the yeast remains upon the bottom of the vat, and does not come into rapid and uniform contact with the fermentable sugar. But if the mash contains certain quantities of spent grain and husks, these serve the yeast as means of transportation, and move about with it in the mash, first rising and then again falling to the bottom, so that the yeast constantly encounters new masses of sugar to act upon. Thus, while the greater part of the spent grain and husks can be removed from the mash without harm, the latter should never be entirely freed from these substances. For this reason apparatus for removing husks should be so designed that it produces a wort but partially free from the solid constituents. Delbrück has shown by special researches that the presence of undissolved substances, which are unaffected by the yeast, neutral substances, has a beneficial effect upon the fermentation, while, on the other hand, a superfluity of such substances is likewise injurious.

Clearing the mash is of advantage because:

1. Through the removal of the husks the mash becomes mobile and more thinly fluid, so that the fermentation progresses with greater energy and rapidity.

2. A certain proportion of the mashing capacity is rendered available thereby, and in place of the useless spent grain and husks fermentable substances can be introduced into the vat, thus increasing the yield from the mashing space. The husks absorb more water than wort from the mash, and thus the room which they uselessly take up cannot be calculated from the dry substance of the husks, according to Heinzelmann.

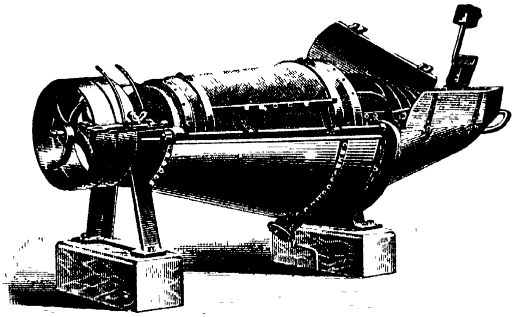

FIG. 37.—MÜLLER-EBERHARDT MASH CLEARING APPARATUS.

3. The space necessary above the mash is diminished, thus offering the possibility of introducing greater quantities of mash into the vat. Carbonic acid adheres tenaciously to the husks and spent grain, and agitates the mash, thus uselessly increasing the volume. On the other hand, carbonic acid escapes more easily from clear worts so that the space above the wort may be restricted in fermenting such liquids.

4. After the removal of husks and other solid bodies,

such as straw or twigs, the mash can be pumped with greater ease and is less liable to choke the pumps during distillation. Consequently, in using clear wort certain alcohol losses which otherwise might occur, are avoided.

The oldest of the systems for removing solids from the mash, which are used to-day, is that of Müller-Eberhardt, built by the Eberhardt Machine Works, Bromberg, Germany. Fig. 37 represents the Müller-Eberhardt apparatus. In this appliance the mash is introduced into a perforated drum by means of a screw conveyer, and is forced out through the sides of the drum by a pressure device. The clearing of mash for a mashing capacity equivalent to 750 gallons takes fifteen to twenty minutes with this apparatus. The device is used in a great many distilleries because of its excellent construction, as well as its uniform and efficient operation. It can be said with truth, however, that it takes up considerable room, three to four square yards, and that it is comparatively expensive; moreover, the power consumption is greater than with other, more modern systems, so that preferably it should be used in larger plants only, which are provided with powerful machinery.

The apparatus designed by C. Leinhaas, Freiberg, Germany, consists of a vertical, cylindrical casing in which is located a perforated cylinder. Within the latter is a conveying screw. The husks are forced upward and are ejected through lateral openings at the upper part of the casing, which is closed by means of a lid. An innovation which has been introduced in this apparatus lies in the peculiar construction whereby the screw and the perforated cylinder can be separately removed for the purpose of cleansing them. The apparatus is provided with a special hoisting device at the upper part of the casing, to assist in the removal of the parts.

The Bohm husk remover includes a brass cylinder in which a screw conveyor is mounted; the mash is fed to the screw by means of the well-known Bohm rotary pump. This device requires little room, as it is preferably mounted directly above the preparatory mash vat itself. Such is also the case with the apparatus designed by Hampel,

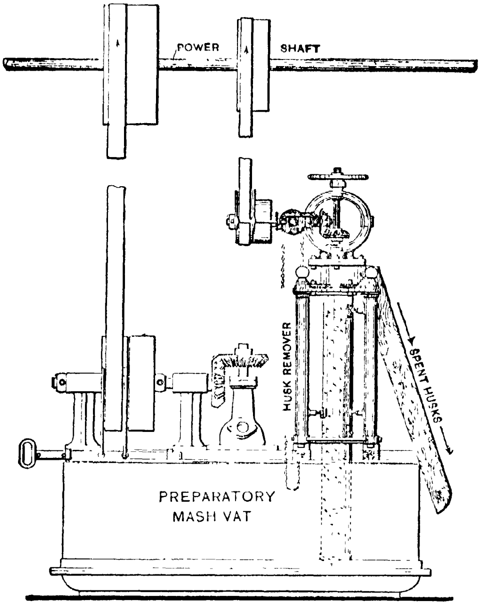

FIG. 38.—HAMPEL'S APPARATUS FOR CLEARING THE MASH.

and constructed by the firm of Edmund Kletzsch, Dresden. This is illustrated in Fig. 38. It consists of a perforated copper cylinder supported by four columns, and provided internally with a screw. The latter draws the mash into the device, forces the husks upward, expresses them, and allows the mash to run back into the preparatory mash vat. The removal of the husks cannot be as complete with this device as with the Müller-Eberhardt and similar types of apparatus, for the entire mash does not pass through the apparatus directly. Nevertheless, with this system too, considerable portions of spent grain can be removed from the mash. The operation is carried out during the cooling period directly after the completion of the saccharization, and thus no time is lost in clearing the mash.

The husk-remover of Hintz-Göbel, Falkenberg, Prussia, is widely used. It consists of a cylindrical casing in which is located a second, vertical, perforated cylinder, and a shaft in the second cylinder provided with spiral, pressing and conveying screw. As the device is located in practice between the prepara-

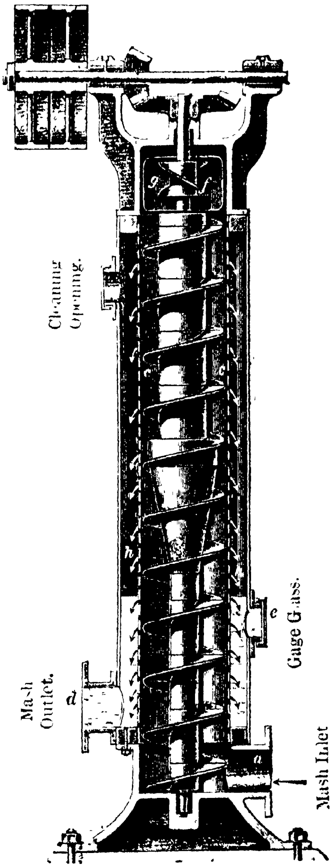

FIG. 39.—THE HINTZ-GOBEL HUSK REMOVING APPARATUS.

tory mash vat and the mash vat proper, it must be so mounted that the outlet pipe of the husk-remover is somewhat lower than the lowest point of the bottom of the preparatory mash vat. This cannot always be accomplished without lowering the apparatus below the level of the floor. In operation, too great a quantity of the mash should not be fed to the remover, for should this occur, part of the mash would be lost with the husks. Thus, it is advisable to provide a suitable cock between the fore-mashing vat and the remover, so that the flow of the mash can be regulated. The apparatus is illustrated in Fig. 39. The cleansing of the device presents difficulties, and it is advisable to provide a steam inlet and outlet by means of which the entire apparatus can be steamed thoroughly.

One of the latest apparatus for this purpose is that of Paucksch, constructed by the Aktiengesellschaft H. Paucksch, Landsberg a.W., Germany. This type has found great favor with many distillers, and has been introduced in a large number of German distilleries. It is illustrated in Fig. 40. The apparatus includes a strong cast-iron shell, in which is located a perforated drum mounted upon a rigid shaft. A screw casing, *f*, in two parts, is provided within the perforated drum. The screw casing is of cast iron and is mounted upon a shaft. A curved plate presses against the inner side of the drum, and is constantly reciprocated by means of an eccentric *l*, mounted upon the main shaft. Pressure is exerted against the curved plate *k*, by means of a spring plate *n*, which is mounted at the screw casing *f*. Besides this, a scraper, *m*, is mounted upon the screw casing *f*, and presses closely against the wall of the drum. In the operation of the husk remover, the mash flows from the preparatory mash vat through the outlet pipe into the rotating perforated drum. The husks collect against the walls of the drum,

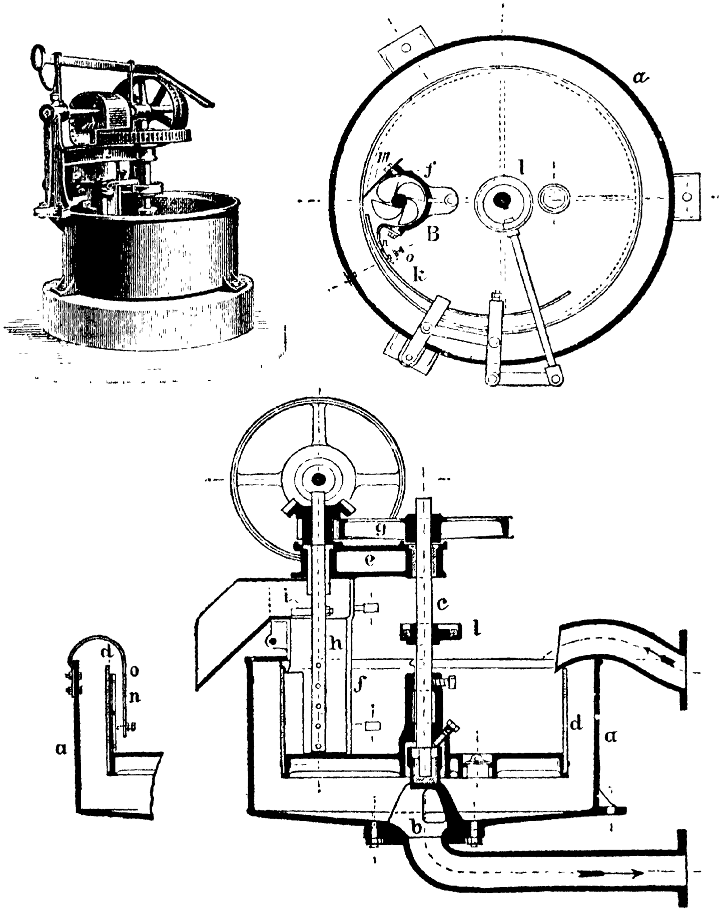

Fig. 40.—The Paucksch Husk-Remover.

while the mash fluid, thrown out through the perforations by centrifugal action, collects in the cast-iron shell *a*, from which it is drawn through the outlet opening by means of a mash pump. The husks collected in the perforated drum pass between the curved plate *k* and the wall of the drum, and are subjected to a preparatory pressing by the reciprocatory movement of the plate. They are then forwarded to the screw by means of the scraper *m*, and by the screw they are forced upward and undergo further pressure. Thus, the perforated drum is constantly being freed from the husks, so that choking of the sieve walls with consequent retarding of the operation is avoided. The Paucksch apparatus requires about one square yard only of floor space, and as it is but 4 feet high, it can be installed without inconvenience. The mash can be introduced into the perforated drum directly from the preparatory mash vat. In a test of this apparatus conducted by Wittelshöfer, 51 pounds of spent grain were removed from 875 gallons of mash, whereby 27 gallons of mashing space were gained. The consequent extra yield of alcohol from this additional quantity of mash would be about 0.4 per cent.

The spiral press invented by Müller is an improved form of husk remover. It is built by the Schleppschiff-fahrt-Aktien-Gesellschaft, of Bromberg, Germany, and is illustrated in Fig. 41. The press comprises the sieve-like body *K*, the conveying screw *F*, and the closed casing *G*, which can be locked and which is provided with inlet and outlet openings *St*, *St*¹. *M* is a continuation of the air tight casing, and is connected with the drum *K*. It is closed by means of the lid *G*. By means of the sweet mash pump, a suction is produced at *St*¹, and the mash is thereby drawn into the perforated body at *St*. The fluid constituent is forced through the openings or perforations, while the solids, which remain in *K*, are seized by the screw *F* and forced along toward *M*. As the casing is air-tight, it acts as a suction air chamber; thus it is but partially filled with the mash, and the residues, in passing toward *M*, soon emerge from the liquid and are expressed in the upper part of the apparatus. After they are completely pressed out they pass into the tube-like addition *M*, and are aggregated solidly until the pressure of the screw

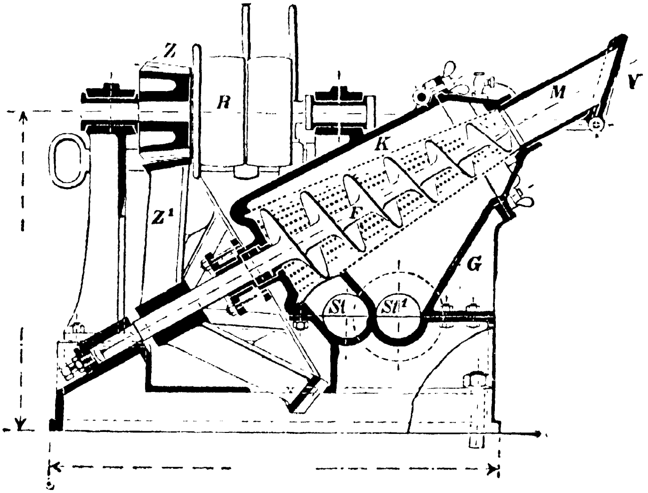

FIG. 41.—MÜLLER SPIRAL PRESS MASH CLEARING APPARATUS.

ejects them, piston-like, from the apparatus. The circumstance that the spent grain and husks are expressed outside of the mash liquid results in the production of drier spent grain than with any other similar machine, and consequently, practically no mash is lost. The following figures evidence the efficient action of the Müller spiral press; it was highly recommended by Heinzelmann as the result of his investigations:

	Hampel	Müller-Eberhardt.	Hintz-Göbel.	Paucksch.	C. Müller.
Water content of the spent grain	74.3	68.7	76.0	73.1	**35.5**
Absolute dry substance	25.7	31.3	24.0	26.6	**64.5**
Husks	21.5	18.0	13.5	15.7	**51.5**

The apparatus is most conveniently set up adjacent to the preparatory mash vat, but it can be located at any desirable point, as long as provision is made for suitable cleansing as the latter becomes necessary. The apparatus requires a space about 3 feet long, 1½ feet wide, and about 1¼ feet high. A special advantage of this system is found in the interchangeability of the sieves; by means of a plurality of sieves of varying mesh, it is possible to take into consideration any possible degree of fineness of the mash, and to clear the latter accordingly.

In choosing any of the above-mentioned husk-removing apparatus, certain circumstances should be taken into account: First of these is the question of space, as the different systems vary considerably in regard to the room they require in the distillery; second is the capacity, which is governed by the quantity of the husks, and the dry substance in the removed waste; and finally there is the power consumption. In the last, the available machine power of the plant must be taken into consideration.

IV.—POWER NECESSARY TO DRIVE THE MACHINERY OF THE DISTILLERY.

W. Goslich, the head of the Mechanical Department of the Institute for Fermentation Industries of Berlin, has made a thorough investigation of modern distilleries with regard to the power consumption of the individual machines and apparatus. These researches are of recent date, and have yielded some interesting results, which can be tabulated as follows:

POWER CONSUMPTION IN THE DISTILLERY.

Apparatus.	Necessary power in effective horse power.	
	First distillery (3 x 750 gallons per day).	Sec'd distillery (3 x 750 gallons per day).
1.—Preparatory mash vat: Maximum requirement	8.09	8.38
Minimum requirement..	4.73	2.46
2.—Sweet mash pump and husk remover	2.68	1.69
3—Malt crusher	2.08	1.95
4—Water pump	2.30	2.06
5.—Two coolers in the fermenting vat........	0.51	——
6.—Potato washer	2.40	——
7.—Feed pump at ordinary boiler pressure....... ..	0.81	——
8—Feed pump at maximum boiler pressure...... ..	1.10	——
9.—Greatest total load upon the steam engine	20.73	19.59

The power consumption of the machines varies with the methods of operation and the loads to which the apparatus are subjected and, especially, with the degree of concentration of the mash. Consequently, the total load upon the power unit, usually a steam engine, fluctuates accordingly. In calculating the necessary size of the steam engine, it is of importance, above all, to take into consideration the auxiliary apparatus, such as grist mills, chaff cutters, threshing machines, etc. Goslich recommends the following sizes for steam engines for distilleries, if no auxiliary apparatus is to be operated simultaneously with the distillery apparatus:

SIZE AND DIMENSIONS OF A STEAM ENGINE FOR A POTATO DISTILLERY.

Capacity of the fermenting vats in gallons.	Diameter of piston in inches.	Stroke in feet.	Revolutions per minute.	Indicated H. P. at 85 pounds pressure.
265	6	0.8	160	6–8
375	7	0.9	150	8–10
500	8	1.0	140	10–12
625	9	1.1	125	14–16
750	10	1.3	110	18–20
1,000	11	1.45	100	24–26
1,250	12	1.6	100	30–34

If auxiliary apparatus are simultaneously operated, the power consumption should be increased by 2 to 4 horse-power for the grist mill, for the chaff cutter 1½ horse-power, and for the threshing machine 6 to 10 horse-power.

V.—COAL CONSUMPTION IN A DISTILLERY.

The investigations made at a large number of distilleries by the Association of Spirit Manufacturers of Germany have shown that the coal consumption may vary largely, even in plants of equal range of production. The coal consumption is dependent upon the size of the vats and the number of mashing operations, upon the quality of the fuel, upon the excellence of the boiler, grate apparatus, and the steam engine, upon the methods of working, and the distilling apparatus in general, and finally upon the expertness of the firemen, the method of firing the boilers, and the general economy of operation. According to Goslich, an expert fireman, who thoroughly understands his business, is able to effect a great saving in coal over that used by one less familiar with the best methods of firing boilers. It would appear that modern distilleries with boilers of proper size, require, inclusive of mechanical vat cooling and heating but exclusive of the requirements of auxiliary apparatus, the following quantities of good, hard coal, with a heating value of about 13,000 B. T. U.:

COAL CONSUMPTION OF POTATO DISTILLERIES.

Capacity of the fermenting vats. Gallons.	Single Operation. Pounds.	**Twofold** Operation. Pounds.	**Threefold** Operation. Pounds.	**Fourfold** Operation. Pounds.
265	185	705	990	1,100
375	660	990	1,435	1,540
550	795	1,215	1,610	1,900
625	880	1,435	1,875	2,250
750	990	1,650	2,205	2,645
875	1,145	1,875	2,535	3,025
1,000	1,280	2,095	2,870	3,420
1,250	1,545	2,645	3,530	4,300

Large distilleries, or plants in which the mashing operations are frequently repeated, require proportionately smaller quantities of coal per unit of vat capacity than those indicated in the table above.

VI.—THE INVESTIGATION OF THE SWEET MASH BY SACCHAROMETRY.

The saccharometric investigation of the mash is based upon the determination of the specific gravity of the mash liquid by means of a hydrometer. The graduations of the latter correspond to the specific gravities of pure sugar solutions, and therefore the instrument is characterized as a saccharometer. The device was first introduced into the distillery by Hermbstädt, and later by Balling and Brix; sometimes the values resulting from the use of the saccharometer are given in "degrees Balling."

The principle of the saccharometer depends upon the fact that sugar solutions possess higher specific gravities than water, and that the higher the degree of concentration of the solution, the higher is the specific gravity. A certain content of sugar in a solution corresponds to a definite specific gravity, as can be seen from the table below.

For the determination of the specific gravities, a glass hydrometer is employed, which when placed in a liquid sinks more easily into a lighter fluid than into a heavier one. Every body immersed in a liquid loses in weight a certain amount corresponding to the weight of the liquid displaced. If a body of this character is immersed in a fluid of a certain specific gravity, it loses less in weight, and consequently sinks more deeply than in a fluid of higher specific gravity. In the latter the loss in weight is greater, and the body consequently sinks less deeply as

TABLE FOR COMPARING THE SPECIFIC GRAVITIES OF SUGAR SOLUTIONS WITH THEIR SUGAR CONTENTS AT 17.5° C. OR 63.5° F., ACCORDING TO BALLING.

Sugar in 100 parts by weight.	Specific gravity.	Sugar in 100 parts by weight.	Specific gravity.	Sugar in 100 parts by weight.	Specific gravity.	Sugar in 100 parts by weight.	Specific gravity.
0	1.0000	20	1.0832	40	1.1794	60	1.2900
1	1.0040	21	1.0877	41	1.1846	61	1.2959
2	1.0080	22	1.0922	42	1.1898	62	1.3019
3	1.0120	23	1.0967	43	1.1951	63	1.3079
4	1.0160	24	1.1013	44	1.2004	64	1.3139
5	1.0200	25	1.1059	45	1.2057	65	1.3199
6	1.0240	26	1.1106	46	1.2111	66	1.3260
7	1.0281	27	1.1153	47	1.2156	67	1.3321
8	1.0322	28	1.1200	48	1.2219	68	1.3383
9	1.0363	29	1.1247	49	1.2274	69	1.3445
10	1.0404	30	1.1295	50	1.2329	70	1.3507
11	1.0446	31	1.1343	51	1.2385	71	1.3570
12	1.0488	32	1.1391	52	1.2441	72	1.3633
13	1.0530	33	1.1440	53	1.2497	73	1.3696
14	1.0572	34	1.1490	54	1.2553	74	1.3760
15	1.0614	35	1.1540	55	1.2610	75.35	1.3824
16	1.0657	36	1.1590	56	1.2667		1.3847 = Saturated sugar solution at 17.5° C. or 63.5° F.
17	1.0700	37	1.1641	57	1.2725		
18	1.0744	38	1.1692	58	1.2783		
19	1.0788	39	1.1743	59	1.2841		

it is proportionately lighter. The depth of immersion of a hydrometer, such as is illustrated in Fig. 42, is in proportion to the concentration of the sugar solution, so that it is possible to estimate the sugar content in the solution from the degree of the immersion of the instrument.

As fluids expand under the influence of heat and contract when subjected to colder temperatures, their specific gravities vary with these conditions, and the determination by means of the saccharometer must, consequently, be made at a definite temperature, usually 59 or 63.5° F., which is known as the normal temperature of the instrument, or the actual results must be calculated to this normal temperature. For this reason, saccharometers which are intended for more accurate investigations are usually provided with thermometers. The graduation of these thermometers always indicates in tenths of a per cent how much must be subtracted from the actual results at lower temperatures, and how much must be added if the temperatures are higher. If the temperature does not correspond with the normal or standard temperature of the instrument, the result can be corrected by means of Steinheil's table given on next page.

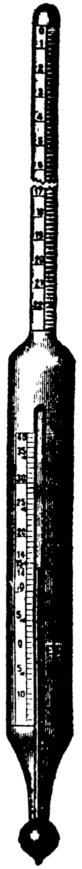

FIG. 42.—THE SACCHAROMETER.

For example, if the investigation at 30° C. gives as result 20° by saccharometer, to determine the content of extract at a temperature of 15.5° C., the saccharometer reading must first be corrected by adding 0.647, which is

STEINHEIL'S TABLE FOR THE CORRECTION OF THE SPECIFIC GRAVITY AND CONTENT OF EXTRACT IN MASHES AT VARIOUS TEMPERATURES.

Specific gravity at 15° C.=59° F.	Correction of the specific gravity for 1° C.	Saccharometer per cent.	Correction of the saccharometer per cent. for 1° C.
1.00406	0.000066	1	0.0163
1.00818	0.000067	2	0.0166
1.01231	0.000069	3	0.0170
1.01655	0.000071	4	0.0175
1.02080	0.000073	5	0.0180
1.02510	0.000075	6	0.0185
1.02943	0.000078	7	0.0192
1.03380	0.000081	8	0.0199
1.03821	0.000084	9	0.0207
1.04265	0.000087	10	0.0215
1.04712	0.000091	11	0.0224
1.05161	0.000095	12	0.0235
1.05613	0.000100	13	0.0247
1.06066	0.000106	14	0.0261
1.06521	0.000112	15	0.0277
1.06977	0.000120	16	0.0296
1.07434	0.000130	17	0.0321
1.07891	0.000145	18	0.0257
1.08348	0.000165	19	0.0397
1.08805	0.000188	20	0.0446

found by subtracting 15.5 from 30 and multiplying the result, 14.5, by 0.0446. The specific gravity corresponding to 20° by saccharometer is 1.08805, and this must be corrected by adding to it 0.00270, which is found by subtracting 15.5 from 30 and multiplying by 0.000188.

The saccharometer can not, of course, be utilized for the investigation of mashes which contain spent grain and husks, and in this case the investigation must be carried out in a mash filtrate. The filter devised by Delbrück is largely used for preparing the filtrate. As evaporation must be avoided during filtration, this operation cannot be conducted in the open. The woven bags, which are used for filtering, are therefore hung in metal cylinders, as is indicated in broken lines in Fig. 43. The mash filtrate collects in the lower parts of these cylinders, and can be withdrawn for investigation through cocks provided at the bottom of each. The mash filtrate is drawn off into suitable glass vessels for the purposes of the test.

The investigation of the mash by means of the saccharometer yields correct results as far as the content of sugar is concerned, if sugar alone is contained in the mash liquid. However, the latter contains other substances, albuminous bodies, amides, etc., and these not always in uniform quantities. In mashes from potatoes very rich in starch there are but 90 parts of sugar in every 100 parts of extract, in those from potatoes poor in starch but 80 parts of sugar, in corn mashes about 95, and in rye mashes about 85. Thus the results of the saccharometer readings are not absolutely correct, but for comparative

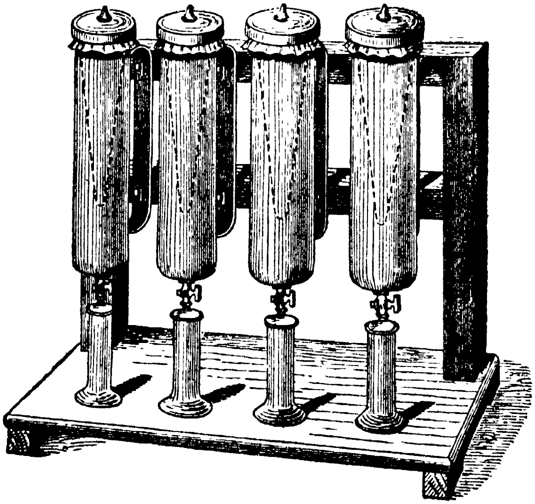

FIG. 43.—DELBRUCK'S MASH FILTER.

purposes this instrument is undoubtedly a very useful device, particularly for determining the quantity of fermented sugar, as that part of the mash extract which disappears during fermentation comprises, necessarily, fermentable substances only. Hence it would appear that the saccharometer is useful rather for comparative determinations than for absolute results. For the latter purpose it is approximate. For instance, it may be assumed that on an average 85 per cent of the saccharometer reading in potato mashes is composed of fermentable substances. Finally, it may be said that from Delbrück's investigations with sweet mashes, it would appear that a clear mash fluid should not be used, but that the liquid which results from a single filtration and is still somewhat turbid should be tested. It is true that turbid filtrates of this character give somewhat higher results, due to the fact that the liquids contain certain quantities of undissolved starch, which during fermentation are converted into sugar by the after-action of the diastase.

VII.—OTHER TESTS FOR THE SWEET MASH.

It is of importance to ascertain whether the sugar formation in the sweet mash has progressed properly. For this purpose the iodine solution affords simple and effective means. A mash, which has been completely saccharified, should evidence no discoloration whatever when tested with the iodine solution. When diastase acts upon starch, the latter either remains untinged by the iodine solution or the following discolorations, in the order named, are produced: blue, violet, red; these correspond to the coloration given to the soluble starch, or particularly, to the dextrins, by the iodine. If a mash shows one of these discolorations, it is certain that the sugar formation has been incomplete, and has been retarded by some injurious agency. In this case it may be assumed that the diastase has been injured or has not completely fulfilled its purpose. As mentioned before, it may be that the diastase does not completely effect the after-fermentation necessary in certain mashes for converting the dextrins into maltose, until it is in the fermenting vat. For investigatory purposes, the quantities of maltose and dextrin may also be determined before and after the conversion of the dextrins by means of hydrochloric acid, by Fehling's solution, assuming that a 20 per cent mash contains about 80 per cent maltose and 20 per cent dextrins, though with concentrated mashes the proportion of maltose to dextrins is somewhat smaller. However, the iodine test is quite sufficient for the purpose of the distiller, that is, as far as it proves by discoloration that the transformation of the starch or dextrins into sugar has not been carried far enough. On the other hand, it cannot be said with certainty, that sufficient active diastase is still contained in the mash if iodine does not discolor the mash liquid, for diastase, after it has completed its action, may be injured through overheating. Therefore, a test with regard to the active diastase in the mash liquid is also necessary. This can be carried out very simply by impasting 5 grammes of starch with 200 cubic centimeters of water, and adding 5 cubic centimeters of the mash liquid after the paste, which is formed by cooking, has been cooled to about 144° F. By the addition of the 5 cubic centimeters of the mash liquid the paste should be liquefied, almost instantaneously, and after half an hour iodine should effect no discoloration whatever in the fluid.

In testing with iodine the mash should be filtered through clean cotton bags until a perfectly clear filtrate is obtained. The filtrate, which should be cold, is diluted with distilled water, and a few drops of the iodine solution are carefully added to it, so that it shows a yellow-red discoloration only. The iodine solution should previously be diluted with water. The first soluble combination formed by the action of the diastase is amylo-dextrin, which is colored a violet blue by the iodine. At a later stage of the formation of this dextrin the discoloration is almost pure violet. When the amylo-dextrin has been partially transformed into the next intermediate substance, achroo-dextrin, the iodine effects a red discoloration. No change is produced by the addition of the iodine solution when the conversion of the starch has proceeded so far that only achroo-dextrin, malto-dextrin, and maltose are present. Thus, the maximum sugar formation has not been reached with the achroo-dextrins, though these show no reaction with iodine. The starch transformation is complete when the achroo-dextrins have been converted into malto-dextrin and maltose. However, notwithstanding that there is no reaction when the iodine is added to solutions containing achroo-dextrins, the value of the test is not impaired, for it has been shown that when the degradation of the starch has reached the stage of the formation of the achroo-dextrins, the progress of the conversion to malto-dextrin and maltose is absolutely certain and is completed with rapidity.

At this point mention should be made of the fact that all the devices for testing and other purposes in distillation, and all like apparatus, are useful then only when they are absolutely reliable. In Germany, the Association of Spirit Manufacturers, as well as the Association of Grain Distillery Owners and Compressed Yeast Manufacturers, whose memberships include practically all the distillers of the German Empire, has for these reasons established a special instrument factory in Berlin. At this factory all checking apparatus, standard solutions, and necessary reagents are prepared and furnished to the distilleries after having been thoroughly tested by expert officials. The uniformity of the instruments and reagents there produced is also of great importance, for by this means uniformity of results in various distilleries is insured.

Finally, the acidity of the sweet mash should always be determined, not for the purpose of drawing definite conclusions regarding the sweet mash, but for the purpose of comparing its acidity with that of the fermented sour mash. During fermentation there is always a certain increase in acidity, due to the activity of acid-forming bacteria, which excite lactic acid, butyric acid, and other acid fermentation. Formerly, it was customary to determine the acidity of the sour or fermented mash only without regard to that of the sweet mash. Now that we know that the sweet mash contains quantities of acid varying between comparatively wide limits, a conclusion of this nature can be drawn only when the increase of acid during fermentation is known. For this reason, the determination of the acidity of the sweet as well as that of the sour mash is necessary. To ascertain the acid content of the mash, 20 cubic centimeters of the filtered mash liquid are used, together with a standard solution of caustic soda. The

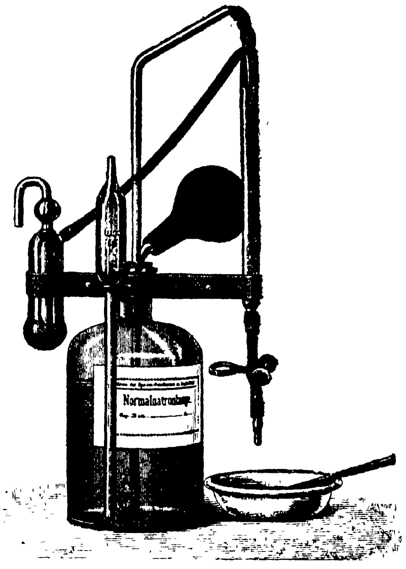

FIG. 44.—APPARATUS FOR THE DETERMINATION OF ACIDITY.

apparatus with which the investigation is conducted is shown in Fig. 44. It comprises a liter flask to receive the soda solution, a burette, graduated in cubic centimeters and tenths of cubic centimeters, which can be filled to the zero graduation by pressing upon the rubber ball with which the device is provided, a titration cup with a glass rod, and a pipette of 20 cubic centimeters capacity.

The investigation is carried out in the following manner: Twenty cubic centimeters of the filtered mash are drawn up by means of the pipette and emptied into the cup. By pressing upon the pinch cock of the burette the standard solution is allowed to flow out slowly, the liquid in the cup being constantly stirred. The standard solution is added until a drop of the liquid taken up with the glass rod no longer colors litmus paper red, but leaves the paper unaltered. The number of cubic centimeters of the standard solution which has been used to neutralize the mash liquid to this point, represents the degree of acidity of the investigated mash. Titration may also be effected in another manner as follows: Twenty cubic centimeters of mash filtrate are diluted in the cup with distilled water and are colored red by the addition of a few drops of litmus tincture. Standard soda solution is now added from the burette until the liquid becomes onion red in color, and the addition of one more drop causes a change to pure blue.

One cubic centimeter of standard solution added to 20 cubic centimeters of mash filtrate represents 1 degree of acidity, and corresponds to 0.09 gramme of lactic acid, 0.06 gramme of acetic acid, and 0.049 gramme of sulphuric acid in the filtrate. For instance, if 0.6 cubic centimeter of the standard solution was used to neutralize 20 cubic centimeters of the sweet mash, the mash possesses 0.6 of a degree of acidity, or, as this quantity is equivalent to 3.0 in 100, the mash would contain $3 \times 0.09 = 0.27$

per cent of lactic acid. The acidity of the sweet mash is due chiefly to the substances of acid reaction, though thoroughly sound, which are found naturally in potatoes.

Besides determining the proportionate contents of maltose and dextrins in the sweet mash, it is of importance as well, to ascertain the quantity of carbohydrates which this contains. In practice the theoretical proportion of dextrin to maltose is not always attained, and according to Bücheler, it is even possible to obtain the maltose and dextrin in the proportion of 8 to 1, notwithstanding that the theoretical proportion is 80.9 parts of maltose to 19.1 parts of dextrin, that is, 4.2 to 1.

To ascertain the content of carbohydrates capable of fermentation, the following method is recommended: 10 grammes of filtered mash are diluted to 250 cubic centimeters, and of the latter 200, corresponding to 8 grammes of mash, are inverted with 15 cubic centimeters of hydrochloric acid of 1.125 specific gravity. The whole is neutralized with a potash solution and diluted to 500 cubic centimeters. Of these 50 cubic centimeters, corresponding to 0.8 gramme of the mash, are used for reduction with Fehling's solution. The 50 cubic centimeters of inverted mash are added to the freshly prepared Fehling's solution, and the yellowish-red cuprous oxide which separates out after the mixture is boiled for a short time, is filtered off and washed with hot water until the alkaline reaction disappears. For filtration, filter tubes provided with long-fiber asbestos held in perforated platinum cones are preferable. Bauer recommends diluting the solution before filtration with double the quantity of water, and cooling to avoid a slight dissolving of the asbestos by the addition of the hot alkaline fluid. The cuprous oxide is first washed with water, and with alcohol and ether to facilitate drying, and is then dried in a copper drying chamber at 230 deg. F. It is subsequently reduced at a moderate temperature in a current of hydrogen, and is allowed to cool in the same current. The hydrogen is then diffused in the exsiccator, and by comparing the weights of the tube before filtration and after reduction, the weight of metallic copper is determined. The dissolving action of the alkaline copper solution upon the asbestos is liable to cause error, and to avoid this, the weights of the tube after reduction and after cleaning with nitric acid subsequent to the washing with water, alcohol, and ether, and after drying, may be used. By means of Allihn's table, given herewith, the dextrose can be determined from the reduced copper. The determination of reduction is always slightly inaccurate, because of the presence of phosphates in the mash. By adding 1 to 2 cubic centimeters of a solution of subacetate of lead to the mash, this error can be avoided. Before the reduction is effected, the lead added in excess should be precipitated with sulphuric acid and filtered off.

Experience has shown that Fehling's solution is reduced one-third less by maltose than by dextrose. According to the investigations of Soxhlet, maltose always separates the same quantity of cuprous oxide, and according to his determinations there is but one uniform proportion of reduction; with the use of a 1 per cent maltose solution, the proportion of reduction resulting is 113 copper to 100 anhydrous maltose. According to E. Wein, the reducing power increases as the solution is diluted, and with a 1/10 per cent solution, the reducing power increases to 119. Wein's table, which follows, is based upon the above investigations. If, for instance, 10 grammes of the filtrate of sweet mash are diluted to 250 cubic centimeters, and 25 cubic centimeters of this diluted filtrate yield 0.1911 gramme of copper with Fehling's solution, this would represent 0.1682 gramme of maltose, or 16.82 per cent according to Wein's table, as 1 gramme of mash filtrate has been used. As the proportion of maltose to dextrose is 100 to 105.3, the dextrose value is 17.71 per cent. If 50 grammes of mash filtrate are diluted to 250 cubic centimeters, and of these 50 are inverted and then diluted to 500 cubic centimeters, and of the latter 25 are used for reduction, yielding say 0.222 gramme of copper, the dextrose content, according to Allihn's table, is 0.1143 gramme, or, as only 0.5 gramme of mash filtrate has been used, 22.86 per cent of dextrose value. By subtracting the dextrose value 17.71 from 22.86, the dextrose value 5.15 is obtained. As the dextrose value is to the dextrin as 100 is to 90, the quantity of dextrin, 4.03 per cent, can be ascertained.

It would appear of advantage to give at this point the method of preparing Fehling's solution. For this purpose pure, recrystallized sulphate of copper, Rochelle salt, and caustic soda are necessary. Dissolve 173 grammes of the Rochelle salt with 60 grammes of caustic soda in about 400 cubic centimeters of water, and after the solution has become cold, make up to 500 cubic centimeters. Powder 34.64 grammes of the sulphate of copper in a mortar, and dissolve in 400 cubic centimeters of cold water. Add 0.5 cubic centimeter of concentrated sulphuric acid, and when the solution is complete dilute to 500 cubic centimeters. The solutions should be kept in separate bottles, and mixed in equal volumes when the Fehling's solution is required. The two solutions should be thoroughly mixed by shaking, or in any other suitable manner. In preparing them, pure distilled water alone should be used. Twenty-four to 30 cubic centimeters of Fehling's solution constitute a suitable quantity for the above determinations.

ALLIHN'S TABLE FOR DETERMINING THE DEXTROSE FROM THE REDUCED COPPER.

Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose.
MILLIGRAMMES.							
10	6.1	52	26.9	94	47.9	136	69.3
11	6.6	53	27.4	95	48.4	137	69.8
12	7.1	54	27.9	96	48.9	138	70.3
13	7.6	55	28.4	97	49.4	139	70.8
14	8.1	56	28.8	98	49.9	140	71.3
15	8.6	57	29.3	99	50.4	141	71.8
16	9.0	58	29.8	100	50.9	142	72.3
17	9.5	59	30.3	101	51.4	143	72.9
18	10.0	60	30.8	102	51.9	144	73.4
19	10.5	61	31.3	103	52.4	145	73.9
20	11.0	62	31.8	104	52.9	146	74.4
21	11.5	63	32.3	105	53.5	147	74.9
22	12.0	64	32.8	106	54.0	148	75.5
23	12.5	65	33.3	107	54.5	149	76.0
24	13.0	66	33.8	108	55.0	150	76.5
25	13.5	67	34.3	109	55.5	151	77.0
26	14.0	68	34.8	110	56.0	152	77.5
27	14.5	69	35.3	111	56.5	153	78.1
28	15.0	70	35.8	112	57.0	154	78.6
29	15.5	71	36.3	113	57.5	155	79.1
30	16.0	72	36.8	114	58.0	156	79.6
31	16.5	73	37.3	115	58.6	157	80.1
32	17.0	74	37.8	116	59.1	158	80.7
33	17.5	75	38.3	117	59.6	159	81.2
34	18.0	76	38.8	118	60.1	160	81.7
35	18.5	77	39.3	119	60.6	161	82.2
36	18.9	78	39.8	120	61.1	162	82.7
37	19.4	79	40.3	121	61.6	163	83.3
38	19.9	80	40.8	122	62.1	164	83.8
39	20.4	81	41.3	123	62.6	165	84.3
40	20.9	82	41.8	124	63.1	166	84.8
41	21.4	83	42.3	125	63.7	167	85.3
42	21.9	84	42.8	126	64.2	168	85.9
43	22.4	85	43.4	127	64.7	169	86.4
44	22.9	86	43.9	128	65.2	170	86.9
45	23.4	87	44.4	129	65.7	171	87.4
46	23.9	88	44.9	130	66.2	172	87.9
47	24.4	89	45.4	131	66.7	173	88.5
48	24.9	90	45.9	132	67.2	174	89.0
49	25.4	91	46.4	133	67.7	175	89.5
50	25.9	92	46.9	134	68.2	176	90.0
51	26.4	93	47.4	135	68.8	177	90.5

ALLIHN'S TABLE FOR DETERMINING THE DEXTROSE FROM THE REDUCED COPPER.—(CONTINUED.)

Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose	Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose
MILLIGRAMMES.							
178	91.1	220	113.2	262	135.7	304	158.7
179	91.6	221	113.7	263	136.2	305	159.3
180	92.1	222	114.3	264	136.8	306	159.8
181	92.6	223	114.8	265	137.3	307	160.4
182	93.1	224	115.3	266	137.8	308	160.9
183	93.7	225	115.9	267	138.4	309	161.5
184	94.2	226	116.4	268	138.9	310	162.0
185	94.7	227	116.9	269	139.5	311	162.6
186	95.2	228	117.4	270	140.0	312	163.1
187	95.7	229	118.0	271	140.6	313	163.7
188	96.3	230	118.5	272	141.1	314	164.2
189	96.8	231	119.0	273	141.7	315	164.8
190	97.3	232	119.6	274	142.2	316	165.3
191	97.8	233	120.1	275	142.8	317	165.9
192	98.4	234	120.7	276	143.3	318	166.4
193	98.9	235	121.2	277	143.9	319	167.0
194	99.4	236	121.7	278	144.4	320	167.5
195	100.0	237	122.3	279	145.0	321	168.1
196	100.5	238	122.8	280	145.5	322	168.6
197	101.0	239	123.4	281	146.1	323	169.2
198	101.5	240	123.9	282	146.6	324	169.7
199	102.0	241	124.4	283	147.2	325	170.3
200	102.6	242	125.0	284	147.7	326	170.9
201	103.1	243	125.5	285	148.3	327	171.4
202	103.7	244	126.0	286	148.8	328	172.0
203	104.2	245	126.6	287	149.4	329	172.5
204	104.7	246	127.1	288	149.9	330	173.1
205	105.3	247	127.6	289	150.5	331	173.7
206	105.8	248	128.1	290	151.0	332	174.2
207	106.3	249	128.7	291	151.6	333	174.8
208	106.8	250	129.2	292	152.1	334	175.3
209	107.4	251	129.7	293	152.7	335	175.9
210	107.9	252	130.3	294	153.2	336	176.5
211	108.4	253	130.8	295	153.8	337	177.0
212	109.0	254	131.4	296	154.3	338	177.6
213	109.5	255	131.9	297	154.9	339	178.1
214	110.0	256	132.4	298	155.4	340	178.7
215	110.6	257	133.0	299	156.0	341	179.3
216	111.1	258	133.5	300	156.5	342	179.8
217	111.6	259	134.1	301	157.1	343	180.4
218	112.1	260	134.6	302	157.6	344	180.9
219	112.7	261	135.1	303	158.2	345	181.5

ALLIHN'S TABLE FOR DETERMINING THE DEXTROSE FROM THE REDUCED COPPER.—(CONCLUDED.)

Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose.	Reduced Copper.	Dextrose.
MILLIGRAMMES.							
346	182.1	376	199.1	406	216.4	436	233.9
347	182.6	377	199.7	407	217.0	437	234.5
348	183.2	378	200.3	408	217.5	438	235.1
349	183.7	379	200.8	409	218.1	439	235.7
350	184.3	380	201.4	410	218.7	440	236.3
351	184.9	381	202.0	411	219.3	441	236.9
352	185.4	382	202.5	412	219.9	442	237.5
353	186.0	383	203.1	413	220.4	443	238.1
354	186.6	384	203.7	414	221.0	444	238.7
355	187.2	385	204.3	415	221.6	445	239.3
356	187.7	386	204.8	416	222.2	446	239.8
357	188.3	387	205.4	417	222.8	447	240.4
358	188.9	388	206.0	418	223.3	448	241.0
359	189.4	389	206.5	419	223.9	449	241.6
360	190.0	390	207.1	420	224.5	450	242.2
361	190.6	391	207.7	421	225.1	451	242.8
362	191.1	392	208.3	422	225.7	452	243.4
363	191.7	393	208.8	423	226.3	453	244.0
364	192.3	394	209.4	424	226.9	454	244.6
365	192.6	395	210.0	425	227.5	455	245.2
366	193.4	396	210.6	426	228.0	456	245.7
367	194.0	397	211.2	427	228.6	457	246.3
368	194.6	398	211.7	428	229.2	458	246.9
369	195.1	399	212.3	429	229.8	459	247.5
370	195.7	400	212.9	430	230.4	460	248.1
371	196.3	401	213.5	431	231.0	461	248.7
372	196.8	402	214.1	432	231.6	462	249.3
373	197.4	403	214.6	433	232.2	463	249.9
374	198.0	404	215.2	434	232.8		
375	198.6	405	215.8	435	233.4		

E. WEIN'S TABLE FOR DETERMINING THE MALTOSE.

Copper.	Maltose.	Copper.	Maltose.	Copper.	Maltose.	Copper.	Maltose.
MILLIGRAMMES.							
30	25.3	72	61.8	114	99.0	156	136.8
31	26.1	73	62.7	115	99.9	157	137.7
32	27.0	74	63.6	116	100.8	158	138.6
33	27.9	75	64.5	117	101.7	159	139.5
34	28.7	76	65.4	118	102.6	160	140.4
35	29.6	77	66.2	119	103.5	161	141.3
36	30.5	78	67.1	120	104.4	162	142.2
37	31.3	79	68.0	121	105.3	163	143.1
38	32.2	80	68.9	122	106.2	164	144.0
39	33.1	81	69.7	123	107.1	165	144.9
40	33.9	82	70.6	124	108.0	166	145.8
41	34.8	83	71.5	125	108.9	167	146.7
42	35.7	84	72.4	126	109.8	168	147.6
43	36.5	85	73.2	127	110.7	169	148.5
44	37.4	86	74.1	128	111.6	170	149.4
45	38.3	87	75.0	129	112.5	171	150.3
46	39.1	88	75.9	130	113.4	172	151.2
47	40.0	89	76.8	131	114.3	173	152.0
48	40.9	90	77.7	132	115.2	174	152.9
49	41.8	91	78.6	133	116.1	175	153.8
50	42.6	92	79.5	134	117.0	176	154.7
51	43.5	93	80.3	135	117.9	177	155.6
52	44.4	94	81.2	136	118.8	178	156.5
53	45.2	95	82.1	137	119.7	179	157.4
54	46.1	96	83.0	138	120.6	180	158.3
55	47.0	97	83.9	139	121.5	181	159.2
56	47.8	98	84.8	140	122.4	182	160.1
57	48.7	99	85.7	141	123.3	183	160.9
58	49.6	100	86.6	142	124.2	184	161.8
59	50.4	101	87.5	143	125.1	185	162.7
60	51.3	102	88.4	144	126.0	186	163.6
61	52.2	103	89.2	145	126.9	187	164.5
62	53.1	104	90.1	146	127.8	188	165.4
63	53.9	105	91.0	147	128.7	189	166.3
64	54.8	106	91.9	148	129.6	190	167.2
65	55.7	107	92.8	149	130.5	191	168.1
66	56.6	108	93.7	150	131.4	192	169.0
67	57.4	109	94.6	151	132.3	193	169.8
68	58.3	110	95.5	152	133.2	194	170.7
69	59.2	111	96.4	153	134.1	195	171.6
70	60.1	112	97.3	154	135.0	196	172.5
71	61.1	113	98.1	155	135.9	197	173.4

E. WEIN'S TABLE FOR DETERMINING THE MALTOSE.—(CONCLUDED.)

Copper.	Maltose	Copper.	Maltose.	Copper.	Maltose	Copper.	Maltose.
MILLIGRAMMES							
198	174.3	224	197.5	250	220.8	276	244.2
199	175.2	225	198.4	251	221.7	277	245.1
200	176.1	226	199.3	252	222.6	278	246.0
201	177.0	227	200.2	253	223.5	279	246.9
202	177.9	228	201.1	254	224.4	280	247.8
203	178.7	229	202.0	255	225.3	281	248.7
204	179.6	230	202.9	256	226.2	282	249.6
205	180.5	231	203.8	257	227.1	283	250.4
206	181.4	232	204.7	258	228.0	284	251.3
207	182.3	233	205.6	259	228.9	285	252.2
208	183.2	234	206.5	260	229.8	286	253.1
209	184.1	235	207.4	261	230.7	287	254.0
210	185.0	236	208.3	262	231.6	288	254.9
211	185.9	237	209.1	263	232.5	289	255.8
212	186.8	238	210.0	264	233.4	290	256.6
213	187.7	239	210.9	265	234.3	291	257.5
214	188.6	240	211.8	266	235.2	292	258.4
215	189.5	241	212.7	267	236.1	293	259.3
216	190.4	242	213.6	268	237.0	294	260.2
217	191.2	243	214.5	269	237.9	295	261.1
218	192.1	244	215.4	270	238.8	296	262.0
219	193.0	245	216.3	271	239.7	297	262.8
220	193.9	246	217.2	272	240.6	298	263.7
221	194.8	247	218.1	273	241.5	299	264.6
222	195.7	248	219.0	274	242.4	300	266.5
223	196.6	249	219.9	275	243.3		

THE COMPOSITION OF THE BEST MASHING RAW MATERIALS.

	Dry Substance.			Nitrogenous Substances.			Fat.			Starch and Sugar.			Other Non-Nitrogenous Extractive Substances.			Total Non-Nitrogenous Substance.			Woody Fibers.			Average Content of Ash.
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average	Minimum.	Maximum.	Average.	Minimum	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
Potatoes	18.0	36.0	24.0	1.5	3.0	2.2	0.1	0.3	0.2	14.0	30.0	18.0	0.5	1.5	0.7	14.5	31.5	19.0	0.5	1.5	0.7	1.1
Barley	80.0	90.0	85.0	6.0	18.0	10.0	1.0	3.0	2.1	55.0	65.0	58.0	1.7	5.0	3.4	56.7	70.0	63.1	2.2	10.8	4.8	2.6
Green Malt, with embryos	48.0	60.0	52.0	6.0	6.5	6.3	—	—	1.5	36.0	42.0	40.0	2.0	3.0	2.5	38.0	45.0	42.5	1.5	7.7	3.2	1.7
Kiln-dried Malt, without embryos	90.0	95.8	92.5	8.0	10.0	9.0	—	—	2.4	64.0	70.0	68.0	0.7	3.7	1.7	64.7	73.7	69.7	2.4	11.0	5.0	2.3
Corn, green	76.0	82.0	80.0	5.5	13.5	9.0	3.0	6.4	4.6	50.0	60.0	56.0	3.8	6.9	6.2	53.8	66.9	62.2	0.9	7.9	2.8	1.4
Corn, dry	84.0	92.0	86.0	6.0	15.0	10.0	3.0	7.0	5.0	55.0	65.0	60.0	4.0	7.5	6.5	59.0	72.5	66.5	1.0	8.5	3.0	1.5
Rye	80.5	91.5	85.0	8.9	17.5	11.5	1.0	3.0	1.7	55.0	68.0	61.0	3.0	8.0	4.9	58.0	72.9	67.9	1.1	3.9	2.0	1.8
Wheat	81.0	92.0	86.0	8.0	24.0	12.5	1.0	3.0	1.7	59.0	75.0	63.0	1.5	6.0	2.4	60.[illegible]	77.4	67.4	1.2	6.4	2.7	1.8
Oats	84.0	92.0	87.0	8.5	18.5	11.7	4.0	7.5	6.[illegible]	[illegible]	62.0	53.0	1.7	4.0	2.1	46.7	66.0	55.1	8.5	16.2	10.8	3.1
											Sugar.											
Molasses	75.5	84.2	81.4	....		...	....	..	...	40.0	55.0	48.0	12.0	18.0	14.0	. .	.....	...				10.8

PART VIII.

FERMENTING OF MASH.

I.—COOLING TO THE FERMENTING TEMPERATURE.

WHERE preparatory mash vats with water cooling are used, special methods of cooling are, of course, unnecessary. In this case the cooling effect is obtained through the water in the cooling elements, assisted by constant operation of the stirring appliance, as it is necessary to cool the mash in one to one and a half hours to a temperature of 63° to 66° F., after the completion of the sugar-forming process. Where, however, direct vat cooling is not available, special cooling apparatus must be provided. In old distilleries the surface cooler or cool-bed was used for this purpose. The oldest form of this device consisted of a flat, rectangular box, in which the mash was manually worked for so long a period that the necessary cooling was effected. This working consisted of constant stirring of the mash with wooden oars or rakes. When motive power and machinery were introduced into the distillery, the cool-bed was altered; it was then constructed in the shape of a flat, round vessel of sheet iron, and was provided with a stirring device wherewith the surface of the mash could be renewed constantly. By means of fans or blowers a strong current of air was forced over the surface of the mash to accelerate the evaporation; by these methods the desired cooling was obtained if the air was cold enough. If, however, the air was warm, the cooling period either lasted inordinately long, or the fermenting temperature of 60° to 68° F. could not be reached, and, thus, it was necessary to allow the mash to ferment at too high a temperature regardless of the evils which this brought with it.

These are the causes of the disappearance of the cool-bed from the distillery. A further reason for abandoning this method of cooling lay in the fact that the surface layer of mash, which was subjected to contact with the atmosphere, of necessity took up from the air germs which induced fermentation. Under favorable circumstances the yeast could doubtless overcome this contamination, but if even the slightest interruption occurred in the development of the yeast, the alcohol yield was diminished considerably in consequence of poor fermentation. Thus, almost without exception, where the mash is still cooled outside of the mash fermenting vat, the cooling is effected with exclusion of atmospheric air, closed coolers being employed. These are almost all constructed on the principle of counter-current cooling, first introduced by Liebig, whereby the greatest possible utilization of the cooling water is obtained. The best known systems of this kind are the tube coolers of Nägeli, Paucksch, Venuleth and Ellenberger, and the lately designed Universal Cooling and Heating Apparatus of Bohm. The last can also be used for heating fluids, and for this reason, has been employed successfully for preheating cleansing and boiler feed water by means of the fermented or spent wort. In general, these cooling apparatus are used more frequently in distilleries which work with attenuated mashes and worts than in those using concentrated mashes. In the latter they are still used of necessity, especially in large plants, where it is desirable to render the mashing apparatus available for subsequent operations as rapidly as possible, and they are usually employed in connection with a number of steamers. The water consumption of these tube coolers is about 1 1/3 to 1½ gallons of water at 54° F. for each gallon of mash cooled.

The Hentschel spiral mash cooler also deserves mention. This is provided with a metal spiral screw located in a tub-like trough. The screw drives the cooling water in a direction opposite to the current of the mash, and as the trough in addition is provided with double walls, effective external cooling is obtained by means of it. The cooling is produced not only by means of the water, but through evaporation as well, so that with regard to its water consumption the Hentschel apparatus is a very economical device.

Still more effective are the sluicing coolers, based on the principle of air and water cooling. These are successfully employed in a great number of distilleries for cooling worts and thin or attenuated mashes. The cooling efficiency of these apparatus is high. For effective operation, uniform sluicing or sprinkling and suitable form of the cooling elements are of great importance. These coolers, like the tube coolers, are not adapted for the effective cooling of concentrated mashes.

The cooling appliance in all modern installations is located preferably in the mashing apparatus. Hampel first introduced this system in the fore-mashing vat designed by him and described in a previous section. The forms of construction of the cooling devices differ widely in the various mashing apparatus built by the different manufacturers. Generally, cooling pockets, coils, or straight cooling tubes are used. Ordinarily cooling tubes or coils are now given the preference because of their simple construction and easy cleansing, especially if they are so designed that they can be taken apart, or can be cleaned without difficulty by means of a cleaning rod or brush. The best material for the cooling apparatus is, without doubt, copper. This metal is to be recommended not only for its superior cooling qualities, but because of its great durability as well. It is superior even to the best cast iron for this purpose. Furthermore, the copper of worn-out apparatus is always of considerable value, whereas iron is comparatively worthless. It may be said, with regard to the water consumption of a preparatory mashing vat provided with efficient cooling apparatus, that as a rule 2 gallons of water at a temperature of 50° to 54° F. are necessary for each gallon of mash.

It is claimed that by means of certain special vats it is possible to effect the cooling in one-half to three-quarters of an hour. Probably this can be accomplished only, however, with the use of very cold water in winter. As a rule, it takes from one to one and a quarter hours to cool the contents of the mashing vat to 61° to 63° F., with a water consumption of 2 gallons of water at 50° F. for each gallon of mashing capacity.

The operation should be in accordance with the following regulations, regardless of the type of the cooling apparatus used: The cooling must be effected without the consumption of excessive power or water, and in a comparatively short time. No decomposition of the mash should occur during cooling. The construction must be such that the apparatus can be cleansed without difficulty, in order to avoid the transfer of ferments to the following mash by adhering remnants of previous mashes. In cooling the mash the heat is transferred to the atmosphere by conduction and radiation, and this transfer can be assisted through evaporation by resorting to so-called air-cooling. The cooling of the mash can be effected by the temperature lowering effect of cold water; this is known as water-cooling. The mash can also be cooled by combined air and water cooling, and by the application of ice to the mash.

Individual distilleries which continue their operations to the warmer season, and utilize river or pond water for cooling, necessarily employ ice to aid in cooling to the fermenting temperature. In using ice it must not be placed in direct contact with the mash, as the latter is diluted and may be contaminated by the ice. To avoid these dangers floats of sheet metal, to carry the ice, are placed in the mash. It may be said with regard to the quantity of ice necessary for cooling that 1 pound of ice in melting absorbs enough heat to cool 79.25 pounds of water through 1° C. or 1.8° F. In practice, the cooling effect is less than this theoretical value; therefore a greater quantity of ice is necessary. Experience has shown that to cool 1,000 gallons of mash at 86° F. to 59° F. about 1,670 to 1,720 pounds of ice are requisite. Thus, it would appear, that the use of ice can be recommended in case of absolute necessity only.

II. ALCOHOLIC FERMENTATION AS IT IS UNDERSTOOD TO-DAY.

Under the term alcoholic fermentation we understand the decomposition, induced by yeast, which certain varieties of sugar undergo, whereby the sugar is split up into alcohol and carbonic acid in accordance with the equation

$$\underset{\text{Sugar}}{C_6H_{12}O_6} = \underset{\substack{\text{Carbonic}\\\text{Acid}}}{2CO_2} + \underset{\text{Alcohol}}{2C_2H_6O}$$

From this equation it would seem that in alcoholic fermentation the sugar is smoothly split up into alcohol and carbonic acid; such, however, is by no means the case, as yeast is an organism which consumes sugar for its nourishment and propagation and also converts sugar into other substances besides alcohol and carbon dioxide during its metabolic changes. Consequently, only about 94 to 95 per cent of the sugar is, on an average, converted into alcohol in accordance with the fermentation formula. One hundred parts, by weight, of sugar, split up directly into alcohol and carbonic acid, would yield 51.11 parts of alcohol, and 48.89 parts of carbonic acid.

Alcoholic fermentation is not the only one which comes into question in spirit manufacture; for certain reasons, as will appear, lactic acid fermentation is purposely excited. Furthermore, against the will of the distiller, butyric acid, acetic acid, and other fermentations arise through the introduction of the corresponding fungi, and these unwelcome appearances materially decrease the alcohol yield under certain conditions. Thus, we are, of necessity, compelled to deal also with these forms of fermentation.

III.—THE HISTORICAL DEVELOPMENT OF OUR KNOWLEDGE OF ALCOHOLIC FERMENTATION.

The production of fermented liquids for drinking purposes, dates back to the days of the ancients, notwithstanding that nothing was known of the nature of fermentation and the fermentation products. The alchemist Basilius Valentinus first recognized in spirit of wine the chief product of fermentation. Van Helmont, a chemist of the seventeenth century, observed that fermentation uniformly produced a certain gas now known to be carbonic acid, though he was unable to determine its nature and characteristics with the chemical means and knowledge then available. The same intelligent student also showed that the ferment (*fermentum*) was absolutely necessary in order to induce fermentation. The German physician and chemist Becher, 1669, regarded fermentation as a process similar to combustion, and stated that the different varieties of sugar only were capable of alcoholic fermentation. Toward the end of the seventeenth century, Stahl promulgated a new theory of fermentation, which obtained for many years. He declared that fermentation and putrefaction were analogous processes, and that the former was but a special form of the latter. The organized nature of yeast was not definitely established until 1836, through the observations of a French chemist, Cagniard de Latour, and simultaneously, though independently, through the investigations of Schwann in Germany. Liebig, however, questioned the correctness of this view and declared that it was a question of pure chemical decomposition, a catalytic process, which could also be effected by unorganized bodies. However, these investigations were soon confirmed by others; Kützing proved the existence of the vinegar bacillus, so that the scientists of that time, including Lüdersdorf, Balling, Kaiser, and Trommer, conceded the truth of the new teaching. The specific characteristics and the organized nature of the yeast were closely studied in France by Pasteur, whose investigations proved that yeast nourishes itself, grows, and increases like many other plants, and these investigations of Pasteur were considered to disprove Liebig's theory completely. Consequently, fermentation came to be considered a process caused by the organic functions and the life of the yeast, that it began and ended with the latter, and that it was not a mere simple chemical decomposition.

E. C. Hansen materially advanced our general knowledge of fermentation, and his investigations embraced the morphological as well as the physiological and biological behavior of the yeast varieties which appear in the processes of brewing. His researches proved that wild races of yeast cause certain of the so-called beer diseases and that these were not, as formerly supposed, due to bacteria alone. By means of pure yeast cultures he closely investigated the character of the different varieties of yeast, and he based upon the results of his observations a system of yeast analysis with regard to the kind and nature of the spores, which is of great importance. This system of analysis resulted from cultures which Hansen obtained from a single yeast cell, and in which he studied the physiological and biological properties of the organism. He showed, further, that there are different races of yeast, that these separate races furthermore embrace different varieties which possess constant properties, and that they retain these properties as long as they are cultivated under the same conditions. It is due to Hansen's work that we are now able to isolate definite races of yeast which produce definite products of fermentation, and impart a definite course to the fermentation. By this use of pure yeast cultures absolutely uniform products of fermentation are always assured if suitable fermenting conditions are maintained.

The view which obtained after Pasteur's investigations were made public was held almost universally until within recent years. That is, until E. Buchner showed, at Berlin, that an expressed liquor could be obtained by mechanical means, strong hydraulic pressure, from comminuted yeast cells, which, notwithstanding that it was passed through filters absolutely impervious to bacteria, and was treated with substances which completely destroyed the plasma, could nevertheless excite fermentation. This investigation proved that an unorganized substance effects the decomposition of the sugar into alcohol and carbonic acid, and that Liebig and others were correct in declaring that the decomposition of the sugar was due to an enzyme. We must now concede that the yeast is but the organism which prepares the sugar-decomposing enzyme, the zymase of Buchner, which splits up the sugar into alcohol and carbonic acid. Nevertheless, the zymase which is separated from the yeast cannot be used for purposes of fermentation. The sugar enters the yeast cell, and is there decomposed by the zymase.

Yeast is not the only organism which possesses the characteristic of producing zymase; many fungi, including mold fungi, have this property. Plants of higher organization also possess zymase, though to a slight degree. The losses which stored potatoes and beets undergo, even with the exclusion of the air, are due to internal fermentation. Green malt also evidences fermentation, especially when worked in thick, warm heaps or couches.

IV.—YEAST THE EXCITER OF FERMENTATION.

The yeast fungus of the beer worts and spirit mashes belongs to the saccharomyces, and because its existence was first demonstrated in beer worts, it is known as *Saccharomyces cerevisiae*. It comprises mono-cellular units; each cell is enveloped by a firm membrane, which is composed of delicate fungus cellulose. The cell contains the protoplasm, a fine viscous granular juice; the cell juice is indicated in the interior of the cell by one or more light-colored zones, vacuoles, which are circularly demarked. Young, vigorous cells contain one vacuole, while older, weaker cells contain several. The vacuoles should be clearly defined and of fair size, neither large nor small. If the vacuoles are barely perceptible the yeast is probably too young for use, and, on the other hand, it is a sign of exhaustion if they are too large. Recently it has been shown that in many cases each cell possesses a nucleus.

The propagation of the yeast occurs in different ways. First, vegetatively, through prolification or the formation of turrion spawn, and secondly, by fructification, through internal, endogenous spore formation. The first method of propagation takes place when the yeast is found in fermenting liquids—it is the one which occurs in spirit mashes and beer worts—and it proceeds as follows: The parent cell at some point of its surface produces a projection which gradually grows to the form and size of the parent cell itself. At the point of junction a little partition wall is formed, which divides the parent cell and the bud or sprout. At the same time, the area of attachment begins to decrease, owing to the constriction and separation of the membrane at the base of the cell formed from the bud till, at length, a very slight strain is sufficient to detach the new cell from the parent cell. In many cases immediately after the separation of the new cell from the parent cell, a new bud is produced at the same place, for there the cell wall is thinnest and most elastic. On the other hand, any point whatsoever on the surface of the parent cell is capable of producing a bud. According to the variety of the yeast, the cells either separate quickly into individuals, or aggregations or chains of spores are formed. Each newly-formed cell at once possesses the ability to act as a mother cell, and to produce sprouts or buds in turn; under favorable climatic conditions a completely developed bud cell can be formed from the parent

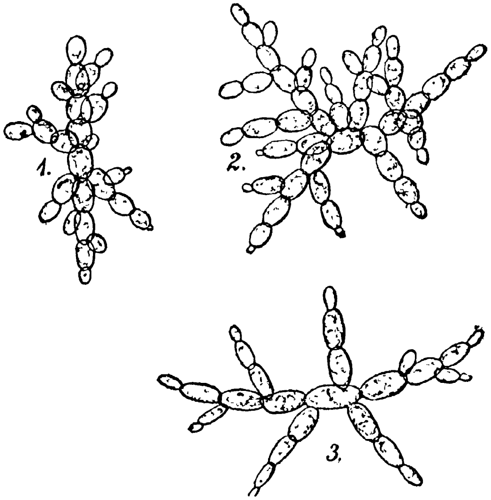

FIG. 45.—GROWING YEAST CELLS SHOWING SQUARROSE AGGREGATIONS. 1 AND 2 ARE OF RACE II., AND 3 IS OF A COMPRESSED YEAST.

cell within a quarter of an hour, and a small number of yeast cells is sufficient to fill completely a large mass of liquid in the short time of a few days. On the other hand, the continued reproduction of the yeast also has an upper limit, and it is impossible to form more than a certain definite quantity of yeast masses in a certain volume of the fermenting liquid.

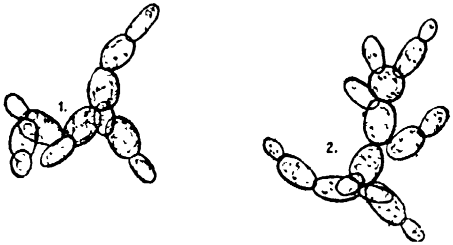

FIG. 46.—LOOSE AGGREGATIONS OF BOTTOM BEER YEAST CELLS AFTER 24 HOURS.

Under proper conditions of cultivation, the spores exhibit peculiar characteristics, by means of which they can be distinguished from each other, and which determine the race of the yeast. Thus, Lindner has recently found that in cultivating yeast in so-called "drop culture," most

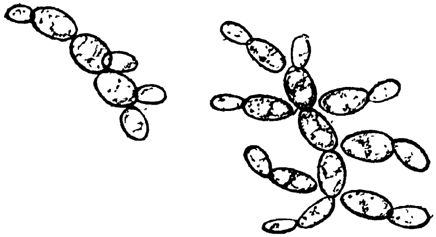

FIG. 47.—A LATER STAGE OF DEVELOPMENT OF THE YEAST CELLS SHOWN IN FIG. 46.

of the compressed, top yeasts (baking yeasts) grow in squarrose aggregations, while others, such as the distilling Yeast Race II and all bottom, beer yeasts, grow in loose, slightly-connected masses. These different types of development are of great value in the biological analysis of mixtures of yeasts. The characteristic appearance of growing yeasts in squarrose and loose aggregations is shown in Figs. 45, 46, and 47.

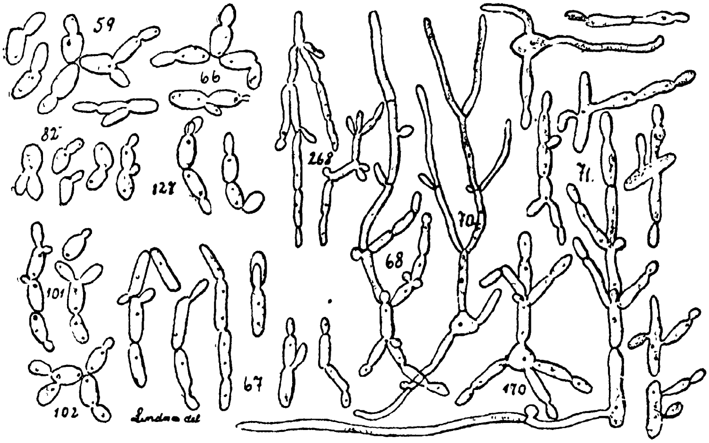

FIG. 48.—CELLS OF 12 DIFFERENT VARIETIES OF MOLD FUNGI, ACCORDING TO LINDNER.

Upon the surfaces of standing fermented liquids covers or membranes sometimes appear which may be fungus formations, due, for instance, to mold fungi. It has been shown, however, by Hansen, that these covers may also consist of peculiar forms of saccharomyces. As a rule they tend to form long cells, as illustrated in Fig. 48.

The second process of reproduction is that of fructification, in which spores are formed in the interior of the yeast cell; this is called endogenous spore formation. The spores are characteristic of all true saccharomyces. As bases for the forming spores, round plasmic bodies appear in the cell and form envelopes, so that usually two to four of these spores, sharply demarked, are discernible in the cell interior. This is shown in Fig. 49. In spore formation it is necessary that the yeast cells be young and well-nourished, and, furthermore, that they be properly spread out upon a moist base or support poor in nitrogen, such as slices of sweet fruit, or sterilized blocks of plaster of Paris, with sufficient access of air. The time or duration of the spore formation at a certain temperature varies with the different varieties of yeasts. This phenomenon provides a means for distinguishing the varieties, according to Hansen. When yeast cells in which spores are forming are introduced into fermentable liquids, the spores begin to swell, burst through the walls of the parent cell, and thus form buds. Yeasts also grow upon solid supports such as gelatine. If even a very small quantity is implanted upon the support, large aggregated masses are gradually formed from it, which are characterized, according to Lindrer, as giant colonies.

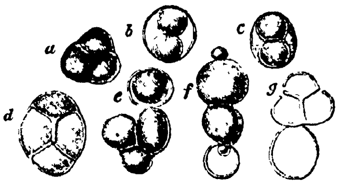

FIG. 49.—SPORE FORMING YEAST CELLS.

V.—PURE YEAST CULTIVATION.

From a practical standpoint, the saccharomyces are divided into two classes, cultivated or artificial yeast, and wild yeast. The latter partially lacks the capacity for endogenous spore formation, while the true saccharomyces, the culture yeasts, all possess this characteristic. The culture yeasts possess the ability, evidently acquired through long processes of evolution, to split up sugar with great energy and rapidity into alcohol and carbonic acid, even in concentrated solutions. It is true that among the wild yeasts there are certain races which possess this efficacy in a high degree; but in general they are inferior to culture yeasts in this respect. Among the culture yeasts there are, as Hansen has shown, certain definitely characterized varieties, which are subdivided into races, and these races possess in a high degree the ability to form alcohol by decomposing sugar. The characteristic has been thoroughly developed, and has been handed down by the yeasts from generation to generation. Therefore, in consequence of the progress science has made in the fermentation industry it has become customary no longer to effect the fermentation through any kind of yeast chosen at random, but instead, to use for this purpose some particular yeast race of well-known characteristics, which has been proven peculiarly well adapted for the purpose. A yeast of this kind, which has been produced by cultivation from a single cell of definite characteristics, is known as "pure culture yeast." In collaboration with Lindner, Delbrück first introduced systematic pure yeast culture, as applied by Hansen to the brewery, into spirit manufacture. The Pure Yeast Culture Institute of the Association of Spirit Manufacturers of Germany, to-day produces the Yeast Race II, which was cultivated in 1889 by Lindner from a cell of distilling yeast at Gronow, Germany, and the Race XII, which was isolated in 1902 by Dr. Matthes. Since we have learned that certain characteristics of the yeast are transmitted to the successive propagative productions of that yeast, we have come to understand thoroughly why the old distillers so carefully preserved their proven varieties of yeast from one working period to the next, even if this preservation lay open to the danger of contaminating or infecting the yeast. To-day however, this preservation of the yeast is no longer necessary, in Germany at any rate, as there the Pure Yeast Culture Institute at Berlin is able to supply the distiller at any time with any quantity of pure culture yeast at slight expense. To-day the Institute produces approximately 22,000 pounds of seed yeast for use in German distilleries each year.

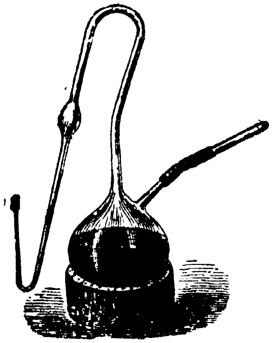
FIG. 50.—THE PASTEUR FLASK.

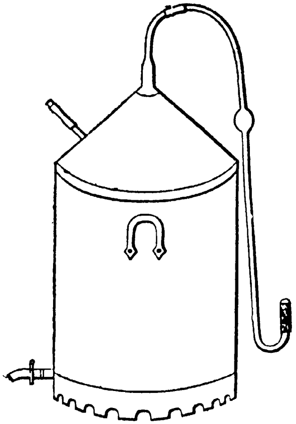
FIG. 51.—THE CARLSBERG FLASK.

The cultivation of pure yeast is carried out as follows: From a mixture of different varieties of yeast, a single cell in vigorous growth is isolated, and is allowed to form a colony in a sterile nutritive solution or gelatine. It is then permitted to develop into masses of culture, observing all the while the greatest care, first in a Pasteur flask filled with sterile wort, and after severals days' growth, in a larger vessel, a Carlsberg flask for further increase. Figs. 50 and 51 illustrate a Pasteur flask and a Carlsberg flask respectively. To insure greater safety in the operation, two preparations should be made. If similar results are obtained from both, it is fairly certain that average specimens have been produced, and that the cells are uniformly distributed. It is absolutely necessary to determine whether or not the gelatine has been provided with a sufficient number of cells; and in order that the cells may be so distributed that pure colonies can be obtained with certainty, the latter, as they are formed, must have sufficient room to intermingle freely with each other. Ordinary glass slips, preferably divided into squares by diamond markings, are employed to hold the drops of culture which are afterward to be used. The squares marked upon the glass are of great assistance in the microscopic examination. If the number of cells is too great, the error can be remedied by adding gelatine; if too small, by adding cells. The gelatine must be kept liquid in the water bath, and the cells must be thoroughly distributed by shaking. The gelatine should, however, be so carefully agitated that the formation of foam is avoided.

The gelatine with the cells should be placed upon glass covers, and these should immediately be covered with glass bells. When the gelatine has coagulated, the covering glass must be inverted that the cultivation may be downward, and the chambers must be fully shut off from the outer air. In two or three days spots of vegetation, visible to the naked eye, appear. In the saccharomyces these have the appearance of minute points of a light yellowish gray color, with either dull or faintly reflective surfaces; when examined under a microscope of low power, the margins appear distinct or uneven. As many as sixty spots of vegetation may be developed in the gelatine film of a single covering glass. Great care must be exercised in transferring the cultivations to the nutritive liquid, and the apparatus must be thoroughly sterilized, while the air must be pure and calm. A pair of small forceps and platinum wires, which have been sterilized in a flame, can be recommended for this purpose. After careful examination, the cells to be transferred to the Pasteur flask are selected, and their boundaries are marked off with a fine brush and a little white color. The covering glass is lifted off its ring, and placed preferably upon a dark background, upside down. The selected spots are touched with the platinum wire held by the forceps and previously sterilized in a flame. The infected platinum wire is inserted through the opening in the flask, and allowed to fall into the same. The flask is heated to 77° to 82° F., and in the course of one or two days there is a well-marked development, if foreign infection has been avoided.

The further development is carried out preferably in the Carlsberg flask after the growth in the Pasteur flask has reached the proper point. The growth developed in the Carlsberg flask is used to develop the yeast in Lindner's pure culture apparatus, in which a mass of yeast can be produced, which is sufficient for pitching a large ventilating mashing vat of 2,000 gallons capacity. Lindner's apparatus is illustrated in Fig. 52; it can be constructed at little expense, is simple in operation, and is particularly suited for working on a small scale. It comprises a Pasteur flask *B* and the copper cylinder *A*, and has usually a capacity of production of about one quart of thickly fluid yeast. The Pasteur flask has a capacity of from eight to ten quarts, while the cylinder, which is some 30 inches long, has a capacity of about seventy quarts. This cylinder has a pipe *C* for steaming and aerating the contents, and for this purpose *C* is provided with perforations and also projects well into the cylinder. The cylinder is further provided with two short tubes, one of which joins with the pipe *C*, while the other is provided with sections of rubber tubing D_3, D_4. E_1 and E_2

are glass tubes; F_1 and F_2 are similar tubes, and for the purpose of air filtration, are filled with cotton. D_1 to D_7 are small rubber tubes. In using Lindner's apparatus, the cylinder A is filled about two-thirds full with fresh wort sterilized by the introduction of steam or by other heating. After about ten minutes, during which steam is allowed to escape slowly, the pipe for the introduction of the steam is closed with a clip and is connected with the sterilized air filter. The wort is then allowed to cool to a lower temperature, either by means of water cooling, or by allowing the apparatus to stand, and the wort is then infected with the yeast from the Pasteur flask B. This is accomplished by withdrawing the tube D_4 from the glass tube E_2, and substituting for it the tube D_5. Unsterilized air, of course, must not be allowed to enter the apparatus during these operations. The cultivated yeast is allowed to run into the cylinder A by raising the flask B, and as the wort must be aerated to supply the yeast with the necessary oxygen, the tube F_2 is connected with a pump, and air is drawn through the filter F_1 and the perforated pipe C into the cylinder. After the aeration is complete, usually after the expiration of one hour, four or five quarts of the infected wort are returned to the Pasteur

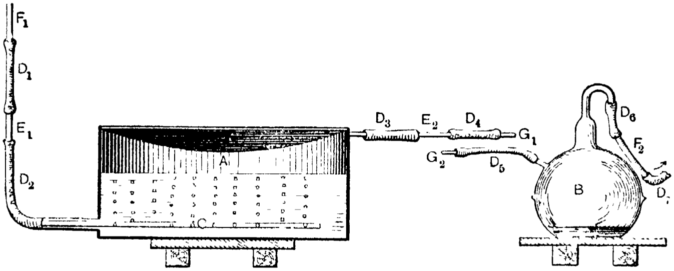

Fig. 52.—Lindner's Pure Culture Apparatus.

flask, and there allowed to ferment to provide sowing yeast for the next fermentation. When the operation is completed, the fluid collected over the yeast in *B* is poured back into *A*. By means of the glass tube E_1 the progress of fermentation in *A* can be readily observed. In emptying the cylinder the fluid is allowed to run out through D_4 until small particles of yeast appear, when the opening is closed with a glass stopper. The cylinder is then vigorously agitated to stir up the yeast thoroughly with the fluid, and the whole is finally allowed to run out. Six days are usually necessary for the cultivation at a temperature of about 60° F. Sometimes the development of the yeast proceeds with such rapidity that in ten hours it is possible to obtain from 10 pounds of sowing yeast as much as 200 pounds of pure culture yeast.

These methods of yeast preparation depend upon the principles which have been developed in the processes of preparing pure yeast in large quantities for practical purposes, and in accordance with the methods of compressed yeast manufacture. Of course, the operations must be carried out under such conditions that the introduction of wild yeast or even of bacteria inimical to fermentation is not possible. The success attending the use of pure culture yeast has been so remarkable that in the distilleries it has been possible to accomplish results with the Yeast Races II and XII, which have never hitherto been attained; these two races primarily, induce pure and active fermentation, so that the alcohol yield is considerably increased. For these reasons it may be recommended with sincerity that every distillery should introduce such effective races. They will be found of the greatest benefit in every distillery.

VI.—THE YEAST RACES.

The cultivated yeasts include two characteristic forms, known as top yeast and bottom yeast. With low fermenting yeasts the yeast mass produced during fermentation in beer worts collects almost entirely at the bottom of the vat, while with high fermenting yeasts part of the latter collects at the bottom and the remainder at the surface of the liquid. However, there are also races of high fermenting yeasts, which form thin surface layers or covers only, and are really intermediate between the high and low fermenting varieties. Other differences can also be distinguished; besides possessing stronger fermentative power, the top yeast inclines more freely toward spore formation, while, on the other hand, bottom yeast less readily forms the characteristic membranes. Bottom yeasts ferment melibiose and melitriose (raffinose) completely, while top yeast leaves the melibiose quite unaffected, and splits up the melitriose into melibiose and fructose, notwithstanding that it is able to ferment the latter alone. The method of distinguishing top yeast from bottom yeast, which has been developed by A. Bau, is based upon this phenomenon. Recently Lindner has observed the appearance of typical spore aggregations in top and bottom yeasts during the growth in drop cultures, and has developed this difference into a valuable method of distinguishing the varieties. Top yeasts, in general, grow in straggling spore aggregations or chains, the characteristic appearance of which, as shown in Figs. 45, 46, and 47, can easily be recognized, even by the layman. Finally, top and bottom yeasts form special groups, which are suitable for particular industrial purposes because of individual characteristics which they possess. Distillery yeasts, especially yeasts for the fermentation of concentrated mashes, must possess the following characteristics:

1. They must be effective, even in poorly saccharified mashes, or mashes weak in diastase; this is the case when they possess diastatic power themselves. Certain wine

yeasts possess no diastase; a number of distilling yeasts are poor in diastase (Saaz yeast). Others again, possess diastase in large quantities (Frohberg yeast). Certain varieties of yeast are capable of saccharifying dextrins (Pombe yeast), and starch (*Amylomyces Rouxii*). The last two varieties, however, are not available for commercial purposes with our present methods of artificial yeast production.

2. They must render albumen digestible for their uses if the mashes are poor in this nutritive substance. The enzyme peptase effects this decompositive process; yeasts which possess too much peptase, however, are easily destroyed through this dissolving of their substance.

3. They must develop strongly, and must ferment with exclusion of the air, for the mashes contain no air during fermentation.

4. They should produce large yields of alcohol, and they must be able to endure the presence of alcohol in considerable quantities if they are to be used in fermenting concentrated mashes. In mother yeasts and in mashes rich in alcohol, injurious fungi cannot exist. Beer yeasts are destroyed by alcohol.

5. They must be able to withstand acids in considerable quantities, for then it is possible to prepare artificial yeast with acid; this use of acid is of advantage, as acid destroys inimical fungi. Beer yeasts cannot withstand acids.

6. They must grow quite strongly, that is, propagate rapidly, for then they overcome injurious fungi.

7. They must be able to withstand heat, for it is possible to complete the fermentation with sufficient rapidity only if it is conducted at higher temperatures. Beer yeasts cannot endure heat. The yeasts must not require too warm a temperature, for at a high fermenting temperature too much alcohol is volatilized.

8. They must endure agitation, for only those mashes which are energetically stirred ferment rapidly and completely.

9. They must be rich in zymase, that is, they must ferment the sugar rapidly; in this case they keep the fermentation pure, and retard the development of inimical fungi by the formation of alcohol and carbonic acid.

10. They must free the mashes automatically from injurious fungi; this is accomplished by poisons which they develop, and by means of which they overcome the harmful growths.

11. They should not make the mash slimy, for if such is the case, they produce foaming fermentation. Race II produces foam, while Race XII does not.

If a yeast race is chosen with these considerations in view, and if the artificial yeast preparation is so conducted that the nourishment provided and the climate are favorable for the development of this race, the yeast will purify itself automatically; Delbrück characterizes such yeast as "natural pure culture yeast." Thus, we understand by cultivated or pure yeast, one from which the fission fungi or schizomycetes and the mold fungi, as well as the spores of wild yeast, have been eliminated as thoroughly as possible, so that the yeast consists wholly of such spores of *Saccharomyces cerevisiae* as are distinguished by the energy with which they induce fermentation, as well as by the purity of the products of this fermentation.

Distilling yeasts are powerful, while brewing yeasts are much weaker. The weaker yeasts soon free themselves from the wort, and the brewers therefore use lees or sediment from the vats for sowing yeast. A similar method of transfer is not feasible in distilleries, because after the mash has been fermented the yeast cells are not as well nourished and vigorous as in the preparation of beer, in fact, they are partly dead and partly very much enfeebled, because of the large quantity of alcohol formed and because of the lack of nutriment.

Growing and fermenting yeast keeps the mash pure, and for this reason it is not advisable to permit the mash to stand without yeast. This is known as the avoidance of dead periods, and it is usually accomplished by adding the yeast to the mash early in the mashing operation. A sufficient quantity of yeast should always be added; the yeast vessel should be equal in capacity to about one-tenth that of the fermenting vat, while the mother yeast vessel should be about one-third the size of the former. The yeast should be thoroughly distributed in the mash, so that the protecting yeast cells inhabit it throughout; the mash must begin to ferment and become active very rapidly, so that the yeast cells may reach all points of it to avert the danger of infection by foreign and inimical fungi.

VII.—FERMENTATION-EXCITING MOLD FUNGI AND BACTERIA.

Certain varieties of mold fungi are capable of inducing fermentation. Under ordinary conditions these form, in the air, long spawn threads, which thicken to barrel-shaped members, and which excite fermentation when they are introduced into solutions containing sugar. These barrel-shaped members, "gems," gradually assume more and more the appearance of yeast-like forms, and increase by prolification. Under these circumstances it is possible to conceive that the *saccharomyces* are descended from mold fungi. Among the mold fungi, *Mucor erectus* possesses the greatest fermenting power, though it can ferment dextrose and levulose only, while *Mucor racemosus* is capable of fermenting dextrose and levulose as well as maltose and saccharose.

The mold fungus *Amylomyces Rouxii*, previously mentioned, not only possesses considerable fermentative power, but a still greater sugar-forming efficacy as well. Within recent times a distilling process, based upon these characteristics, has been developed for this fungus. The schizomycetes also include varieties which form alcohol; among these are the *Bacterium prodigiosum,* the *Bacillus Fitzianus* and even a pathogenic variety, the *Bacillus pneumoniae* (Friedländer), which all produce alcohol fermentatively from sugar.

VIII.—THE DEVELOPMENT OF HEAT DURING FERMENTATION.

As the total energy contained in the sugar is greater than the combined energies of the products of fermentation, carbonic acid and alcohol, energy in some other form must arise during the decomposition. This surplus energy set free during the fermentation appears in the form of heat. It is well known that every fermenting liquid produces heat in a decided measure, and under certain circumstances the temperature of the fluid may be considerably increased. The greater the quantity of sugar split up during fermentation, the greater is the heat developed. Theoretically, through the decomposition of 1 pound of cane sugar and maltose, or 1.053 pounds of dextrose and levulose, whereby 0.511 pound of alcohol is obtained, 66.6 B. T. U. are developed; that is, 25 gallons of mash could be raised in temperature over 1.2° F. for each per cent of fermented sugar. Thus, 20 per cent of fermented sugar would correspond to a temperature increase of 54° F. Fermenting mashes never actually heat as much as this, and, in general, mashes of 20° by saccharometer, containing 18 per cent of sugar, are raised about 31.5° F. in temperature; with 20 per cent of fermented sugar the mash is heated through 35° F. This difference between the actual and the theoretical heating is due to the escaping carbonic acid, which carries with it warm water and alcohol vapor, as well as to radiation and conduction, through which large quantities of heat are lost. Nevertheless, the heating of the mash is not inconsiderable, and under certain circumstances it may even be injurious to the fermentation, and may require special consideration in the operations, for instance the application of vat cooling devices.

IX.—SUBSTANCES SUITABLE FOR THE NUTRITION OF THE YEAST.

Yeast is a plant, and therefore requires nutritive substances of organic, nitrogenous and non-nitrogenous, as well as mineral form. The chief non-nitrogenous organic nutritive substance for the yeast is found in sugar. Among the nitrogenous nutritive substances of greatest importance are the amides, including asparagin; these are found in considerable quantities in potatoes and malt. The yeast can also utilize ammonia combinations; among the albuminoids, the peptones are fairly good nutrients, though ordinary albumen is hardly suited for this purpose. Among the mineral substances, yeast chiefly requires phosphate and potassium salts, and, on the other hand, but very small quantities of magnesia and sulphur combinations. In practice the mineral substances are of no importance, as they are found in sufficient quantity in the mashing materials. Therefore, it is still an open question whether or not it is of advantage to add potassium phosphate during the fermentation; 'at any rate, fermented potato mashes always contain sufficient soluble phosphate and, especially, potassium salts. Pure compressed yeast comprises 25 per cent of dry substance and 75 per cent of water; 100 parts of the dry substance consist of 63 per cent of albuminoids, 32 per cent of non-nitrogenous substances, such as cellular substance, fat, and glycogen, and 5 per cent of mineral substance. The albumen content varies within wide limits, and the fermenting power rises or falls with the percentage of albumen in the yeast. For this reason the yeast should be strongly nourished with albumen.

X.—THE FERMENTING TEMPERATURE AND THE SUBSTANCES INJURIOUS AND FAVORABLE TO FERMENTATION.

The energy of the fermentation-inducing action depends chiefly upon the warmth of the fermenting liquid, if we neglect the characteristics of the yeast itself. The most favorable degree of heat for the distilling yeasts which have so far been investigated, approximates 86° F. Therefore, during fermentation this point must, under no circumstances, be exceeded. A 10 per cent sugar content is most favorable for the propagation of the yeast; after this quantity of sugar has been fermented the increase in the yeast ceases, and the further fermentation is carried out by the previously-formed yeast. Nevertheless, we have long since learned how to ferment 26 to 27 per cent concentrated mashes. The alcohol which gathers in the fermenting fluids decreases the energy of the yeast reproduction as well as that of fermentation. The carbonic acid too, which collects in a fermenting liquid is injurious with regard to the yeast reproduction, and is also inimical to fermentation. At any rate, this is the view which obtains at present, and the rapid removal of the alcohol and carbonic acid by the agitation of the mash, must therefore be regarded as favorable to fermentative action. The carbonic acid, however, also has a favorable action as it induces motion in the mash. Certain substances in small quantities have an exciting effect upon the latter, while in larger quantities they injure or arrest the fermentative action. To the last class belong all the acids; among those which have the most powerful action are hydrofluoric acid and hydrochloric acid, while sulphurous acid and sulphuric acid have weaker effect, and lactic acid and tartaric acid act upon the fermentation least vigorously of all. Volatile fatty acids also tend to arrest fermentation; among these is butyric acid, which does so very energetically. As these substances, including butyric acid, are also powerful bacteria and yeast poisons, a predetermined and proper quantity of any one of them provides an active means for assisting the yeast in overcoming competitive fungi. Investigations conducted by Delbrück and Lange have shown that an artificial yeast which has become accustomed to butyric acid remains pure under the influence of this acid for a longer period than when assisted by pure lactic acid. Alkalies completely arrest the propagation of the yeast and the fermentation, and for that reason all fermenting fluids must contain a certain quantity of acid.

XI.—SUBSTANCES CAPABLE OF FERMENTATION.

Only varieties of sugar having the composition $C_6H_{12}O_6$, such as dextrose (glycose) and levulose (fructose), are directly capable of fermentation. All other varieties of sugar which are encountered in spirit manufacture, for instance, cane sugar (saccharose), $C_{12}H_{22}O_{11}$, and maltose, $C_{12}H_{22}O_{11}$, are not directly fermentable, but by means of certain enzymes of the yeast they must first be converted into fermentable sugars—cane sugar into invert sugar, which is a mixture of levulose (fructose) and glycose (dextrose), and maltose into glycose, by the enzymes invertase and glucase respectively. Certain yeast races, which do not contain such transforming enzymes are unable to ferment the corresponding varieties of sugar. Thus, for instance, the most powerful distilling yeasts cannot ferment milk sugar, and for this purpose a special yeast, found in milk, is necessary.

XII.—SUBSTANCES PRODUCED BY FERMENTATION.

The strongest yeast, developing and fermenting under complete exclusion of oxygen, produces as main fermentation products alcohol and carbonic acid from about 94 per cent of the fermented sugar, while about 6 per cent of this is changed into other natural and unavoidable metabolic substances, chiefly succinic acid and glycerine. The appearance of the glycerine can probably be ascribed to the decomposition of the lezithin, as well as to the activity of the fat-decomposing enzyme, lipase. We know that dying or weak yeast produces greater quantities of by-substances in the form of organic acids and, principally, fusel oils. The evolution of the latter should not, however, be entirely ascribed to the weakening or destruction of the yeast, as certain of the raw materials, such as corn and other grains, lend themselves more readily to the production of greater quantities of the fusel oils, than do potatoes; furthermore, certain bacteria are probably concerned in the formation of the fusel oils. The chief constituent of the latter is amyl alcohol. They also include, however, a large number of other alcohols of the same group, such as propyl alcohol and butyl alcohol and their isomers. Certain yeasts also produce aromatic ethers, and others sulphureted hydrogen.

The following quantities of alcohol can theoretically be produced from 1 pound of the corresponding carbohydrates, with the practical assumption that 6 per cent of the sugar is uniformly changed into by-products:

	Theoretical.	From 94 per cent of fermented sugar.
100 pounds of dextrose free from water	7.3 gallons	6.8 gallons
100 pounds of cane sugar and maltose	7.7 gallons	7.2 gallons
100 pounds of starch............	8.1 gallons	7.6 gallons

or 100 pounds can produce:

	Alcohol.	Carbonic Acid.
Dextrose free from water	51.11 pounds	48.89 pounds
Cane sugar and maltose	53.80 pounds	51.46 pounds
Starch	56.78 pounds	54.32 pounds

XIII.—SCHIZOMYCETES (BACTERIA) IN THE DISTILLERY.

Among the most unpleasant phenomena in the distillery are the schizomycetic fermentations produced by fission fungi, especially those which are inimical to the growth and fermentative efficacy of the yeast. Thus, it is the chief aim of the distiller to suppress the exciters of injurious fermentation and the bacteria in general, as far as this is possible with the present means afforded by the science of fermentation, and to keep the fermenting liquids free from these fungi. Fig. 53 illustrates varieties

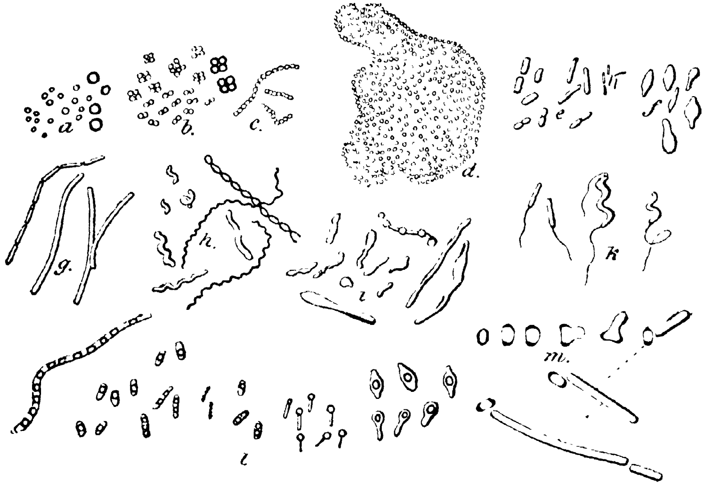

Fig. 53.—The Development and Spore Formation of Various Schizomycetes.

of fission fungi in different stages of development. To protect the fermenting liquids it is absolutely necessary to introduce into them protective substances which leave the desired fungus, the yeast, unmolested, and which permit it to develop undisturbed by the schizomycetes. For this purpose lactic acid has proven itself to be particularly suited. Science has enabled us to make use of the lactic acid fungus, which also belongs to the fission fungi, for the production of this acid. To-day, this fungus is regarded with great favor in the distillery, and is cultivated to protect and assist the yeast.

It is characteristic of bacteria, that they are extremely sensitive to acid reactions in the culture medium, and their development in acidulated fluids is either so retarded or so completely stopped that they are unable to cause injury. For this reason, lactic acid fermentation is purposely induced in yeast mashes, in which it is desired to accomplish the reproduction and cultivation of as pure and fermentatively active a yeast as possible. Lactic acid fermentation is excited by many varieties of bacteria; so far, it has not been possible to ascertain their number even approximately.

Among the lactic acid bacteria there are certain kinds with stronger or weaker acid-forming efficacy; and as in the preparation of the yeast it is of great importance to excite as strong as possible a souring, it is advisable to use for this purpose those kinds only which possess the greatest souring or acid-forming power. As in the similar case of yeasts of definite characteristics, the lactic acid bacteria can be produced by pure cultivation, and the most effective lactic acid bacillus, which has so far been discovered, is that developed by Lafar in Behrend's laboratory at Hohenheim, the *Bacillus acidificans longissimus.* Pure lactic acid culture may be obtained in Germany from the Pure Yeast Culture Institute at Berlin. In investigating the physiological characteristics of twenty-three different races of lactic acid, which will appear in distilling mashes and worts, W. Henneberg (Institute for Fermentation Industries) found that they are of widely differing value for the purposes of the distillery, and that but few of them are capable of producing sufficient quantities of acid to insure the non-appearance of schizomycetes inimical to fermentation. For this reason it is advisable to use thoroughly tested lactic acid cultures only, just as pure culture yeast alone should be used to-day, for then only are good results assured during the subsequent operations. Certain lactic acid bacteria, which form acetic acid as well as lactic acid, are directly injurious to the yeast. Lactic acid fermentation is a simple decomposition of the sugar molecule into two lactic acid molecules, as

$$\underset{\text{Dextrose}}{C_6H_{12}O_6} = \underset{\text{Lactic Acid}}{2C_3H_6O_3}$$

The resulting lactic acid is easily soluble, not crystalline in form, and is of syrupy consistency. It has an acid reaction, but is without odor, and forms a great number of salts which crystallize easily.

The products of butyric acid and butyl alcohol fermentation are less injurious to alcoholic fermentation than the development itself of the bacteria which induce these fermentations. The exciters of these forms of fermentation belong largely to the bacterial genus *amylobacter*, which present a remarkable difference in their development and their fermentation-inducing characteristics from those of the lactic acid bacteria. They develop most strongly at blood temperature, 99.5° F., while at 122° F. they barely develop at all. On the other hand, the latter temperature is most favorable for the development of the lactic acid bacteria, and consequently, to lactic acid fermentation, so that under the maintenance of this temperature, pure lactic acid fermentation is attained, which, in consequence of the strongly acid reaction, does not permit the other bacterial fermentations to arise. In the lactic acid fermentation in the yeast mash the greatest attention should be paid to the temperature, and under no circumstances should this be allowed to fall below 122° F., for should this be the case, injurious varieties of bacteria would settle in the mash and would produce the poisons which are harmful to the yeast. The inimical lactic acid bacteria flourish at 99.5° F.

Acetic acid fermentation is also caused by different varieties of bacteria, and particularly, through the transfer of oxygen to the alcohol formed by the alcohol yeast, in accordance with the formula

$$\underset{\text{Alcohol}}{C_2H_6O} + 2O = \underset{\text{Acetic Acid}}{C_2H_4O_2} + \underset{\text{Water}}{H_2O}$$

The most perfect cleanliness only, is effective against the acetic acid bacteria, which consume the alcohol of the mash, but exclusion of the air is also of assistance, for without the co-operation of oxygen the vinegar fungus is unable to form acetic acid. There are certain varieties of vinegar fungi which transform the sugar into acid. As the strongest acetic acid formation takes place at higher temperatures only, which are no longer employed in fermenting mashes, it is hardly to-day a source of great danger in the distillery. On the other hand it is encountered with great frequency in certain yeast factories, and the souring of the yeast can largely be ascribed to the action of acetic acid bacteria.

PART IX.

THE PREPARATION OF ARTIFICIAL DISTILLERY YEAST.

BEFORE the mash can be fermented, the exciter of fermentation, the yeast, must be prepared in proper quantity and in a suitable manner. The yeast is produced from an available seed yeast or "mother yeast," or at the beginning of the operation, from a known pure culture yeast, which is propagated in a suitably prepared yeast mash. It is allowed to increase in the latter so that ripe yeast of the highest fermentative power and free from micro-organisms inimical to fermentation is obtained. The strength and purity of the fermentation are not alone dependent upon the method of yeast preparation, but the latter influences the character of the fermentation as well. The yeast must be in the proper physiological condition. If it is in too luxurious a state it produces foaming fermentation; if properly ripened, it induces smooth and lasting fermentation. Brewer's yeast can be used for fermenting mashes; but as it is not always possible to procure a supply of this, it is important that the distiller should be familiar with the methods of yeast preparation, to insure a successful yield of alcohol at all times.

I.—THE PREPARATION OF THE YEAST MASH.

The mash is prepared from malt, with the addition of grain or, more frequently, sweet mash; a yeast mash of this character contains all the nutritive substances necessary for active yeast propagation. For the preparation of an effective yeast mash and a proper yeast, it is necessary, above all, to provide a nutritive base free from bacteria. For this reason the malt or other raw material, such as malt germs, which is used for the preparation of yeast, must be thoroughly cleansed and must be free from all organisms detrimental to fermentation.

Malt and unsoured potato mash have sufficient quantities of amides; these are the nitrogenous nutritive substances best suited to the yeast. Furthermore, a yeast mash prepared from these materials provides all the other nutrient mediums requisite for the development of the yeast, particularly sugar and mineral substances. Green barley malt is usually employed for this purpose, though oat malt, as well as a mixture of rye and oat malt, gives equally successful, if not better, results. The yeast mash must be as concentrated as possible, for experience has shown that the cultivation of pure, fermentatively active and ripe yeast is possible in such mashes alone. Consequently, a yeast mash of at least 20° by saccharometer, if possible of 22° to 24°, should be provided. As this is not possible with green malt and water alone, a certain quantity of sweet mash must also be used for the production of a yeast mash of this concentration. The formation of sugar from starch, through diastatic action, should be conducted at 131° F., the temperature before complete saccharification being increased to 155.5° F. or even to 162° F. Although this procedure somewhat weakens the diastase, the germs of injurious bacteria are rendered harmless thereby. This sterilization at high temperature is possible in very concentrated mashes only, and after the greatest possible quantity of sugar has been formed, for thereby the diastase is rendered fairly indifferent to the higher degrees of heat. In working potatoes poor in starch, water is not added at all, and sweet mash and double-crushed green malt only are used for the yeast mash. The yeast remains purer in concentrated yeast mashes because the fermentation of the greater quantities of sugar, which these mashes contain, yields more alcohol than in thinner mashes. Alcohol is a very powerful schizomycete poison, and, furthermore, is just as strongly inimical to unsuitable yeasts, which are suppressed by this means. Nowadays the infection caused by fission fungi is seldom a danger in the preparation of concentrated yeast mashes. The alcohol also accomplishes the maturing of the yeast.

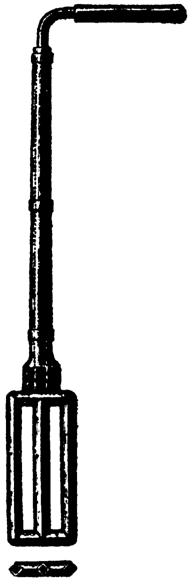

FIG. 54.—THE SCHEIBNER STEAM MASHING OAR.

The starch present in the malt must be dissolved and transformed into sugar as completely as possible. As malt starch is liquefied at higher temperatures only, the mashing of the yeast mash must be carried out at comparatively high degrees of warmth; these are furthermore necessary for the suppression of the fission fungi, which are introduced into the mash partly through the malt, partly by means of the air. The mash is, therefore, worked as described above, with a final sterilizing temperature of about 160° F. for fifteen minutes, after being carried at the lower temperature for about an hour.

With especially good raw materials the high final temperature may be neglected. With doubtful materials it is necessary, and under no circumstances injurious; it should always be employed if a large quantity of malt is used. This was formerly the case with the green malt yeast which was produced from malt and water merely. In the yeast mashes customary to-day, the mashing process is carried out as follows: With mashes rich in sugar, 3 to 8 gallons of water at 185° to 194° F., according to the quantity of the residue to be mashed, are placed in the yeast vessel, and with constant stirring the crushed green malt is added so that through the mashing action a fine malt milk is produced. To this is added the sweet mash from the preparatory mashing vat, the yeast vessel being gradually filled with constant stirring. The sweet mash should be freshly saccharized, and should be as free as possible from husks. To attain the desired final temperature after the completed working of the yeast mash, hot water or steam is used. In the latter case the Scheibner steam mashing oar is often employed; this is illustrated in Fig. 54. It consists of a tinned copper, steam oar, having at one end a copper frame provided with fine perforations. The opposite end of the oar is bent at right angles, and can be connected with the steam supply of the distillery by means of a suitable rubber hose. The middle portion of the oar is jacketed with wood so that it can be grasped without danger. The yeast mash is vigorously stirred by means of this oar, with constant flow of steam through the device, until the desired temperature is reached. Larger distilleries have special apparatus for yeast preparation, with stirring devices and steam pipes, as illustrated in Fig. 55. The construction of this apparatus is similar to that of the fore-mashing vat; the vat is usually of iron. It has an inner facing of copper and for the better retention of the heat is double-walled. In certain forms of apparatus the steam can circulate within the double walls, while in others it is introduced into the vessel by means of an inner pipe system. Heinzelmann considers this form of apparatus of special value when the yeast mash is not only mashed therein but is also soured and set with yeast in the vessel. By means of devices such as these the preparation of the yeast mashes in large plants has been considerably cheapened and simplified. The souring and

cooling, furthermore, can be accomplished with greater ease and more thoroughly in accordance with the proper regulations than in a process involving a large number of smaller mashes. Yeast mash apparatus is constructed by nearly all the machine manufacturers engaged in the building of distillery appliances.

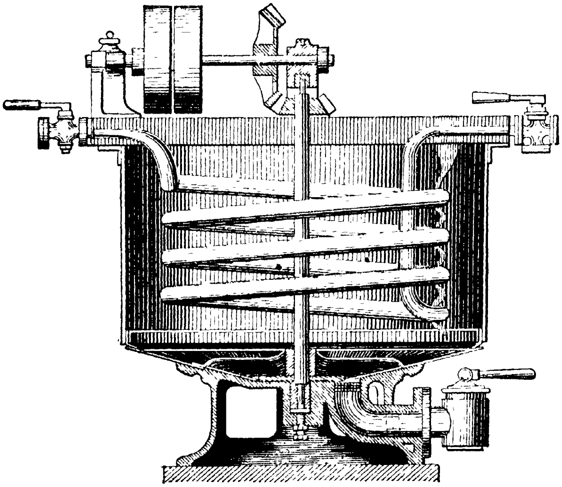

FIG. 55.—YEAST MASHING VAT.

1.—The Preparation of Yeast from Green Malt.

The fresh green malt in a finely crushed condition is placed directly in the fermenting vat, about 4½ pounds of the malt being used for each 25 gallons of vat capacity. Water at 151° F. is added in the proportion of about two-thirds of a quart for each 4½ pounds of malt, and the mass is energetically worked to a uniform paste, which, at first thick, soon becomes more thinly fluid during the operation. Half the quantity of water previously added is now poured into the vat at about 190° to 200° F., with constant stirring. The mixture is allowed to stand for about an hour at a temperature approximating 150° F. for saccharization, and the mash, which is now very thin, is allowed to sour at 113° to 126° F. A period of ten hours is usually sufficient for this purpose. The mash is rapidly cooled to 54.5° to 60° F., and the mother yeast is then added; the latter develops rapidly and induces fermentation which decreases the former saccharometer indication of the mash by about one-half. When this point has been reached, the yeast required for the following mash is removed, and the remainder is set with sweet mash at a comparatively cool temperature. The sweet mash generally is of 16° to 17° by saccharometer, and the souring is carried to a point such that 1.6 to 1.8 cubic centimeters of standard solution are sufficient for the neutralization of 20 cubic centimeters of mash. The preparation of yeast from green malt as a rule takes about two days.

Yeast mash prepared from green malt is extremely thin, and it has been found that a more concentrated yeast material, which possesses an equally vigorous fermentative power can be prepared from grain grist and crushed malt. Crushed rye is often employed for this purpose, the grist being used in the proportion of 1 part to 2 parts of crushed malt. In preparing the mash, the grist and the malt must be intimately mingled.

By altering certain steps of the mashing process it is possible to reduce the time for souring and for yeast growth to twenty-four hours. The shortening of the time is effected principally by adding a few quarts of sweet mash to the sour yeast mash from the previous operation, at temperatures such that the temperature of the mixture is about 110° F. The sweet mash should preferably be at a temperature of 144.5° F., while the sour yeast mash may be at the temperature of the room. When the sour mash is in full activity it is added to the sweet mash, and the whole is then cooled to about 125° F. Souring, which is completed in a short time, is now immediately induced.

2.—Preparation of Yeast With Kiln-Dried Malt.

In preparing yeast with kiln-dried malt more water is required than in the working with green malt, though otherwise the processes are similar. Three and three-tenths to 4.4 pounds of the dried malt, with 3 quarts of water at 151° F., are used for each 25 gallons of vat capacity.

3.—Preparation of Yeast With the Avoidance of Dead Periods.

According to Delbrück, the intervals during which foreign organisms develop most dangerously, are two in number. They are the one between the completion of the souring and the pitching with the mother yeast, and that between the time when the mother yeast is taken off in the morning and the pitching with mother yeast in the evening. Each of the intervals is of about nine or ten hours duration. To avoid these dead periods, J. E. Brauer proposed this method: First, sour yeast material with a small addition of calcium bisulphide is introduced early in the mashing. Secondly, cooling is commenced at 122° F. and is carried rapidly over the dangerous temperatures. The yeast is added during the cooling, at about 88° F., and is developed with rapidity while the operation is continued to 54.5° F. Any injurious fungi which may have accidentally entered the material are thus effectually suppressed by the low temperature as well as by the strongly-developed yeast.

4.—Preparation of Emergency Yeast.

It often happens in the distillery that the yeast mash, for some reason or other, becomes spoiled, and if other yeasts were not obtainable the operation would have to be interrupted. Under such circumstances resource can be had to beer yeast, compressed yeast, or preferably, pure culture yeast. The sweet mash, to which the yeast has been added in the proportion of 2.2 to 3.3 pounds of yeast for each 25 gallons of mashing capacity, is allowed to ferment at a temperature of 84° to 88° F., for two or three hours, before setting the large vat, and is then added to the chief mash. Souring can be effected by the addition of sulphuric or hydrochloric acid, but it is preferable to add a quantity of sour yeast material to the sweet mash.

5.—The Preparation of Hop Yeast.

Hop yeast is prepared mainly in the United States. It is produced by the growth of wild yeast cells originating in the air, and, notwithstanding the views of scientists that it is possible to obtain pure and satisfactory fermentation from cultivated races of yeast only, surprisingly good results are obtained with the assistance of concentrated hop extract. When examined under the microscope, yeast produced by this method appears to be pure and strongly developed. The hop extract kills the bacteria so that sweet yeast material, instead of sour, can be used. According to Schrohe the yeast is prepared in the following manner: The extract is obtained by long-continued boiling with steam, the hops being cooked with a determined quantity of water. One pound of hops is used for each bushel of malt, and with the assistance of the hop extract, a malt extract of 15° to 18° saccharometer is obtained. Roughly crushed malt of the best quality only should be used. The extract, preferably at a temperature between 167° and 200° F., is added to the malt, and after standing from one to three hours, it is again drawn off through the bottom of the vat. After cooling to 66° F. the extract is allowed to stand, care being exercised that the temperature does not fall materially below this point. In a few days the yeast is soured by wild yeast cells introduced from the air. It is then fermented for a period of from twelve to eighteen hours and is poured into a stout copper vessel with a tinned lining, provided with an airtight lid and a small cock. The yeast in the vessel when stored on ice will keep for weeks and sometimes even months. The vessels should be filled about nine-tenths full; they are easily emptied by reason of the pressure of the carbonic acid developed therein. The yeast is then ready for use either for pitching yeast material, or for strengthening the mother yeast.

6.—Partenheimer's Mash Yeast.

In this process sweet mash is forced through a perforated plate or sieve and cooled to 129° F. It is allowed to stand at 122° F. with repeated stirring, until its acidity is about 1.5°. About thirty hours after the beginning of the mashing operation, the material is rapidly cooled to 77° F., the souring meanwhile having progressed to about 2°. Previously, about a tenth of the material is removed for later use. About 1 gallon of mother yeast is added to every 5 gallons of the mash, at 77° F., and the mixture is then allowed to ferment. No malt is used in this method.

II.—SOURING THE YEAST MASH.

After the mashed yeast material has stood at the mashing temperature for about two hours for the purpose of saccharization, vigorous lactic acid fermentation is allowed to set in as protection against inimical organisms in the mash. The lactic acid is necessary because schizomycetes are incapable of development in strongly acidulated fluids. Furthermore, lactic acid possesses a peptonizing action upon albuminous substances. The latter, through this action, become available for the yeast.

That the development of the acid in the yeast mash may not be dependent upon chance alone, and in order to avoid the danger of the production of unsuited races, it is necessary, at the beginning of the operation, to introduce suitable cultures, and to keep the material in a pure condition by maintaining it at the proper souring temperatures. To show how inexpensive this operation may be, a small flask of lactic acid culture obtained from the Pure Yeast Culture Institute at Berlin, for 1 mark, or 25 cents, is sufficient for a yeast vessel having a capacity of 40 gallons.

It is of great importance that the yeast mash be soured very rapidly, and for this purpose it may be infected with sour yeast mash from a previous operation, by the introduction of pure cultures, or, if necessary, by the addition of a few quarts of sour milk. The souring is allowed to progress to 1.8° to 2.5° of acidity, according to the method used.

If the lactic acid fungi have once located in a distillery, the souring of the yeast mash will doubtless continue of its own accord. It is, however, much safer to effect the souring of the yeast mash by the addition of previously soured mash from earlier operations, and thereby to continue the use of the same race in the distillery by means of infection. In this, however, certain considerations must be taken into account. Heinzelmann, for instance, warns us of the danger of adding too great a quantity of the sour mash, for in this case such large quantities of lactic acid are set free in the mash that they may prove dangerous to the diastase. It is necessary to permit the mashing material to stand for at least an hour for complete saccharization, and to refrain from adding the sour mash before cooling to 128° F. has been effected; 1 gallon of sour yeast mash is necessary for 200 of yeast mash. Even if the mash sours with difficulty 2 gallons will probably be quite sufficient. The action of the diastase must, under no circumstances, be retarded by the lactic acid. The sour yeast mash which is added to the sweet mash should, according to Kopplin, never be allowed to cool to a low temperature. If it cannot at once be used for souring it must be placed in a vessel in warm water and maintained at a temperature of about 131° F. A comparatively smaller quantity of a yeast mash of this kind should be used, as the danger of injuring the diastase through the lactic acid is then less imminent.

For the production of as pure as possible an acid the souring must proceed at those temperatures which are most favorable to the development of useful lactic acid bacteria. It has been shown that the best temperatures for this purpose lie between 122° and 131° F. In distilleries using concentrated mashes, the souring period is usually twenty to twenty-four hours. To maintain the previously mentioned souring temperature during the entire period, it is necessary to provide a warming chamber for the manufacture of the yeast. This should be large enough to contain only the necessary number of souring vessels, and it must be provided with heating apparatus wherewith it can be warmed to the desired temperature, with the consumption of little steam. Sometimes the souring temperature is regulated by repeated heating with the steam mashing oar. The yeast chamber should be kept uniformly warm, and the sides of the yeast vessels should be coated with concentrated mash; at the same time the latter should be covered with wooden lids upon which are placed bags or straw matting. Preferably, the vessels should be so formed that the covers are depressed and airtight, so that hot water can be poured into them.

Experiments have shown that lactic acid itself renders the acid ferment weak and ineffective. Thus, it has long been known in practice that little acid is formed during fermentation if the yeast mash is very sour. From this it is evident that strong souring is of great advantage in suppressing the growth of schizomycetes in the yeast mash, as well as by impairing the vitality of the lactic acid ferment. In consequence, the yeast when transferred to the chief mash is thoroughly developed and vigorous, and is able to induce pure alcoholic fermentation, while at the same time, it is capable of overcoming every by-fermentation. Though the lactic acid ferment is detrimental to alcoholic fermentation, it is beneficial to the yeast during the stages of its development. It has been shown that lactic acid present in small quantities, not over 1 per cent, assists fermentation, but if the content of the acid increases to 2 per cent, fermentation is arrested. Other acids and salts affect the fermenting process, though in varying degrees, in the same manner as lactic acid. As said before, Delbrück holds that the power of injuring fermentation through lactic acid is rendered ineffective by heating the sour yeast material after the completion of the souring, to 167° F., and maintaining it at this temperature for about a quarter of an hour. This heating does not kill the acid ferment, but it weakens it so materially that it is incapable of exerting its injurious activity after the mother yeast is added.

III.—THE USE OF TECHNICAL ACIDS TO REPLACE FERMENTATIVE SOURING.

As the cultivation of the lactic acid fungus, described in the previous section, requires not only a series of special appliances, but also great care and close observation by a conscientious, experienced, and trained distiller, the replacing of fungus souring by chemical agents of antiseptic nature has long been the object of researches and experiments by fermentation experts. The technical acids, especially, have in recent times been employed as attempted substitutes for natural souring. For certain of these acids special methods have been developed. The use of the acid was always proposed with a view to avoiding the necessity of lactic acid fermentation and, with the hope of thereby simplifying the method of operation by shortening the period of yeast preparation, usually forty-eight hours, to twenty-four hours. The following methods are of importance in this connection.

1. *Fluoric acid yeast.* The valuable characteristics which fluoric acid possesses as a bacteria poison for distilling mashes, were first recognized and more closely investigated by Effront. He showed that a yeast which was gradually accustomed during a long period to increasing quantities of fluoric acid could be developed in such a manner that it was capable of withstanding fluoric acid in quantities which were not only poisonous for the bacteria, but which would otherwise have been inimical to the yeast itself as well. Yeast accustomed in this manner to fluoric acid was found able to withstand quantities of the acid far greater than any of the bacteria detrimental to fermentation. With the proper use of this method, and with the maintenance of certain determined conditions, which the inventor has made public in a process patent, fluoric acid can be used with success in the distillery. Cluss has investigated the fluorides, especially fluoride of aluminium, as substitutes for fluoric acid, and has used them with success in mashes. The fluorides were used in quantities of ½ to 1 ounce for each 25 gallons of mash. It would appear that the use of the salts is preferable to that of the acid directly.

2. *Technical lactic acid.* The first attempts to use technical lactic acid were carried out in yeast factories by Dr. Wehmer, while Dr. H. Lange first investigated the same substance with regard to its utilization in potato distilleries.

The result of the latter's investigation showed that this acid could be used profitably in place of the lactic acid fermentation induced by fungi. The quantity of the acid which is used for the purpose approximates 1 gallon for each 100 gallons of yeast mash. In fact, in one distillery excellent results were obtained by the use of 0.5 to 0.7 gallon of the acid per 100 gallons of mash.

If too much lactic acid were used the setting in of the fermentation would be delayed. With the quantities of acid given above, such was not the case. The souring in the vat, the alcohol yield, the degree of the fermentation, etc., were all excellent, and we may assume from these experiments that the replacing of the natural lactic acid by the technical acid can be successfully accomplished. In yeast preparation of twenty-four hours duration the method with the technical lactic acid would be as follows:

The requisite quantity of lactic acid, about half a gallon per 100 gallons of yeast mash, is added after the completion of the mashing period and after the yeast mash has stood for about two hours at 144° to 146° F. for the purpose of saccharization. With a view to preserving the diastase, the lactic acid need not be added until 122° F. is reached during the cooling period. Of course, it would be a mistake to wait until the pitching temperature of the yeast were reached before adding the lactic acid; for it is well known that under 122° F. organisms detrimental to fermentation locate in the mash, and if the lactic acid does not appear until later their suppression is incomplete, or, at any rate, not fully assured. Naturally, it is unnecessary to maintain the yeast mash set with lactic acid, at the souring temperature for a longer period, and it may immediately be cooled to the pitching temperature. In using the technical lactic acid there is the advantage that a series of operations in the preparation of the yeast is avoided, and, furthermore, the desired degree of acidity can be attained with certainty. It is merely a question of whether or not the attainable advantages more than balance the increased cost due to the addition of the lactic acid. It is certain that greater expense is incurred, due to the high price of the acid, which obtains to-day. It is hardly to be expected that the new method will be introduced generally into properly ordered distilleries, but it doubtless will be found of use in case of interruptions in the operations, or if apparatus for the usual fungus souring are not available. It must be understood that technical lactic acid cannot be used without fully understanding the process. Thorough attention must be given to the quantity of acid to be added, as well as to the method of conducting the fermentation, the temperatures to be maintained, and other necessary phases of the working.

3. *The process of producing artificial yeast with the aid of lactic acid and volatile fatty acids, and without fungus fermentation.* During the course of the experiments which Delbrück undertook with a view to using lactic acid as a substitute for the fungus fermentation, it was noticed that the minute quantities of butyric acid which occurred in the impure lactic acid of commerce did not possess an inimical action with regard to the yeast. For this reason H. Lange studied a number of artificial yeasts for a considerable period, gradually augmenting their acidity by the addition of increasing quantities of butyric acid. It was possible to bring the butyric acid content to a point such that its destructive action with regard to the schizomycetes was far stronger than that upon the efficacy of the yeast. Yeasts carried under the protection of this acid remained pure for a much longer period than when provided with pure lactic acid. However, the process, which in the interests of the Association of Spirit Manufacturers of Germany is protected by patents, has so far found no practical utilization.

4. *The proposed use of mineral acids as substitutes for*

fungus fermentation. Dr. Bücheler has developed a process for the utilization of sulphuric acid, which is characterized by the regulation of the acid added by means of a special titration method, in which the yeast is provided with so much sulphuric acid only, that the organic salts naturally present in the mashing material are decomposed, whereby organic acids are liberated, while the mineral acid itself remains inactive. By means of this method, too, artificial yeast preparation is materially simplified; better results, however, than with the lactic acid fermentation method in common use, have not been attained. It remains to be discovered whether or not the introduction of this process will pay for the patent fees by simplifying the manufacture of artificial yeast.

5. *The use of yeast extract for lactic acid yeast or sulphuric acid yeast without malt, according to Bauer's patent.* This process is characterized by the use of a special yeast extract produced from the substances of the yeast through self-digestion. This extract is antiseptic, and may be added to the yeast mash in working with both lactic and sulphuric acids. The extract contains those substances which are especially suitable for the nourishment of the yeast, particularly nitrogen combinations and phosphate in large quantities, and it is especially adapted for use in mashes which are poor in such substances, for instance, in molasses mashes. At the present time this extract costs 80 pf. per kilogramme in Germany, that is, about 8 cents a pound. According to Bauer's figures one pound of the extract is sufficient for 1,500 gallons of yeast mash. This process, however, has not as yet found general utilization in potato distilleries.

IV.—STERILIZATION OF THE YEAST MASH BY MEANS OF HEAT.

When the lactic acid formation has progressed to the desired point, that is, when the yeast mash has attained a degree of acidity of at least 2, possibly 2.5 to 3 cubic centimeters of acid (determined by a corresponding quantity of standard solution), the mash is warmed by means of the steam mashing oar to a temperature of 167° to 176° F. in order to destroy thereby the lactic acid and other bacteria. This raising of the temperature is, according to the present standpoint of our knowledge, of great utility, and should be carried out regularly in every distillery. The lactic acid bacteria which are suppressed thereby, have accomplished their purpose and should be precluded from the further operations.

The application of this degree of heat to the yeast mash has not found favor with all practical distillers, as further acid formation is thereby suppressed. The heating to 167° to 176° F. to destroy the lactic acid fungi is thus justified only when a vigorous souring has already been effected. Should this not be the case, the warming of the mash may have directly injurious results. Therefore, it should always be determined by ascertaining the acidity of the mash whether or not the required souring has been produced. Should this souring not have progressed far enough the mash should not be raised to the high temperature mentioned, in order to provide an opportunity for the production of the requisite acidity through a possible after-action of the lactic acid bacteria. Under certain circumstances this hope may not be fulfilled. In general, weak lactic acid formation in the mash should not occur. If the quantity of lactic acid formed is not satisfactory, it is either due to the fact that the souring temperature was maintained at too high a point or that unsuitable lactic acid races were present. In the latter case, there should be no hesitation in procuring new, pure lactic acid cultures. The mother acid for souring the yeast mash on hand should be removed *before* warming the mash.

V.—COOLING THE YEAST MASH.

After the mash has been warmed and allowed to stand for about half an hour, it is cooled to the pitching temperature. Attenuated yeast mashes should be pitched at a lower temperature than concentrated mashes, for the danger of the development of inimical organisms is greater with higher than with lower temperatures, and in a thin mash it is especially prominent because of the smaller alcohol quantities produced therein. For this reason a thin mash should be cooled to 59° F., while in a mash of 20° saccharometer the higher temperature of 63° to 68° F. may be chosen, as the yeast develops more rapidly and soundly, and without danger of infection. In cooling it is necessary to pass rapidly over the dangerous temperatures between 95° and 113° F., which are favorable to the development of schizomycetes, and, therefore, it is absolutely necessary to provide powerful and rapid cooling, especially between these temperatures. All care in the preparation of the yeast is unavailing if detrimental fungi are given the opportunity to develop through conditions, arising with slow cooling, which are favorable to their growth. Formerly it was believed to be sufficient to introduce a rigid cooler in the yeast mash and to permit the cooling water to flow through this cooler. Such devices generally consisted of double-walled, cylindrical vessels, or of cooling coils which were constructed of flat, wrought copper pipes.

The cooling water was simply permitted to flow through coolers of this kind, and the mash was manually or mechanically stirred from time to time. For rapid cooling, rigid devices of this construction are not effective. Vigorous cooling should be provided by making the coolers movable, by arranging them so that they are at the same time adapted to act as stirrers, or by providing for the constant agitation of the yeast mash, in order to aggravate the cooling action. Such cooling devices may be actuated either

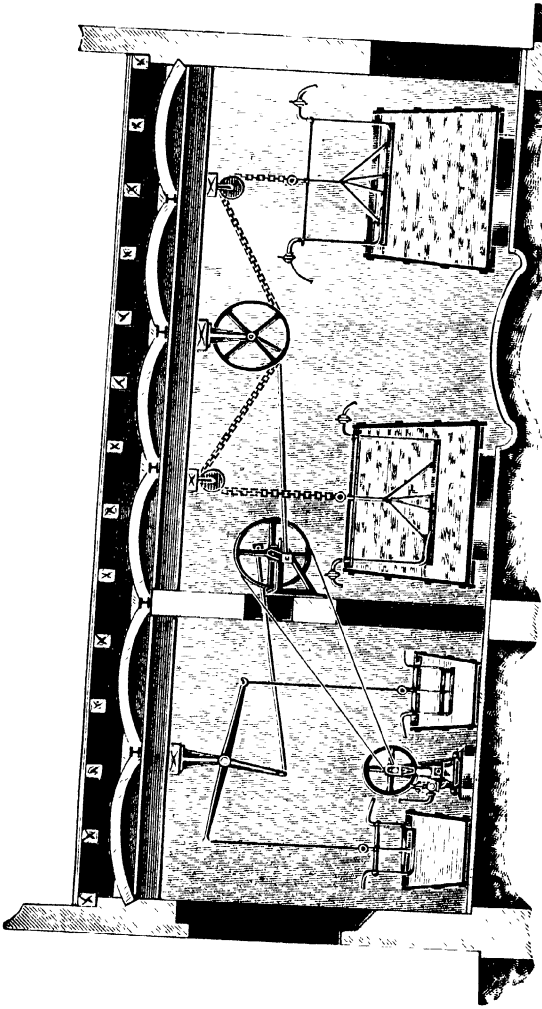

FIG. 56.—MOVABLE COOLING APPARATUS FOR YEAST AND FERMENTING VATS.

by mechanical power or by the cooling water itself. Coolers driven by mechanical power are connected by means of suitable transmission devices with the motive power of the distillery; they consist of copper cooling coils which are moved up and down in the mash. Sometimes the distillery is provided with a small, separate steam engine, which can be kept in operation beyond the usual working period of the plant, by means of the residual steam remaining in the boilers, and which can be used for driving the movable, fermenting vat cooling devices of the chief mash, as well as for the operation of the yeast cooling and warming coils. An installation of this character is illustrated in Fig. 56.

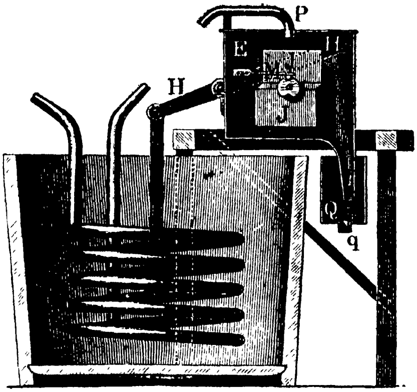

Fig. 57.—Bohm's Automatic Yeast Cooler.

Yeast coolers which are driven by water power vary substantially in construction. The cooler of this type constructed by Bohm is illustrated, for example, in Fig. 57. The cooling water, which enters through the pipe *P*, first flows into the upper one of two tipping cups *J*, *J*, which are rotatably mounted upon a shaft and are held in a horizontal position by means of a spring *M*. When the upper cup is filled the weight of the water rotates the shaft upon which it is mounted, and the water is emptied out into the encasing tub, hung by means of rods upon the lever *H* which is secured to the cooling coil, the latter being raised thereby. As soon as the water has escaped from the casing the cooling coil returns to its depressed position, and thus the action continues regularly as the cups are alternately filled and emptied.

VI.—THE ADDITION OF THE MOTHER YEAST TO THE YEAST MASH.

The mother yeast is added during the cooling of the yeast mash. It takes place when the cooling has progressed to approximately 86° F. Under the term mother yeast is understood the portion of the yeast which was withdrawn from the previous yeast preparation, when it had attained a condition of "ripeness." It is advisable so to regulate the individual operations of yeast preparation, that the yeast mash to be set is at the proper point for the addition of the mother yeast when the yeast, which is undergoing fermentation, has reached that point of ripeness best suited to the removal of the mother yeast. By this method the standing of the yeast mash for a longer period is avoided; this should always be accomplished, if possible, to prevent the occurrence of "dead periods," which are liable to cause considerable injury. Furthermore, in the yeast processes care should be taken that each individual operation is followed directly by the succeeding operation, and that no periods of rest intervene, as these are favorable to the infection of the yeast. It may be said, then, that under no circumstances should a period of rest of longer duration be permitted between the ending of one operation and the beginning of the next. According to the old methods of yeast preparation, the cooled yeast was allowed to stand for a considerable time before it was pitched, and this was a dead period which undoubtedly was dangerous. A further danger lay therein that often no attention was given to preparing the yeast in such a manner that it was ready exactly at the time when it was to be added to the chief mash. Often the yeast was already complete on the evening previous, and was allowed to stand overnight; during this period it became weakened and was exposed to the danger of infection. A yeast which had become weakened in this manner had to be freshened, that is, it had to be brought to a higher point of fermentative efficacy by the addition of warm sweet mash, and hereby it was again exposed to the danger of infection because of the dilution of the protecting acids. This danger is avoided by so preparing the yeast that it is ready at the exact time when it is to be used, as thereby this dangerous freshening of the yeast becomes unnecessary. At this point mention should again be made of the fact that the mother yeast used for the fermenting of the chief mash should, under all circumstances, be derived from a known and approved race. If a distiller believes that he possesses a particularly effective race he should, of course, keep that race and use it in the distillery; it is preferable, however, at the beginning of the operation, to provide a race intended for concentrated mashes, and to propagate the mother yeast from this. It is also advisable to renew the original supply of pure culture yeast from time to time. It cannot be definitely stated how often this should be done; the experience and knowledge of the distiller must decide this question, for it often happens that in one place yeast degenerates more rapidly than in another. At any rate as soon as there is the slightest interruption or decrease in the yield, pure yeast culture, as well as pure lactic acid culture, should be provided, and no time should be wasted in attempting artificial betterments.

The mother yeast is introduced into the yeast mash at a temperature such that its reproduction can begin at once—that is, at about 86° F. The mash should then immediately be cooled to the best temperature under the local conditions obtaining; this temperature depends especially upon the degree of concentration of the yeast mash, the temperature of the fermenting room, and the size of the yeast vessels. There should be no delay in the progress of the cooling, for at 86° F. the conditions are extremely favorable to the development of injurious schizomycetes.

VII.—FERMENTATION AND YEAST DEVELOPMENT IN THE YEAST MASH.

After the introduction of the mother yeast, the spore-forming activity and the fermentative action of the yeast begin. Strangely enough, it is not advisable to provide conditions favorable to the development of these functions; instead, such climatic conditions are imitated that the suppression of inimical fungi is effected in accordance with the principles of the "natural pure culture," which were advanced by Delbrück in 1895. Suitable means for overcoming injurious schizomycetes are found in vigorous souring and in the alcohol produced by thorough fermentation by the yeast itself. It was formerly an open question whether or not the yeast mash should be allowed to ferment strongly or weakly; but it has to-day been decided that in order to keep the yeast pure, it is absolutely necessary to ferment the mash strongly, that the greatest possible quantity of alcohol may be produced therein, as we know that the alcohol is inimical to the development of detrimental micro-organisms. Yeasts which have fermented weakly are easily infected; but, of course, under favorable circumstances, good results may be obtained with them, though they are always extremely uncertain in operation. Therefore, it is necessary to permit a yeast of 20° to 24° by saccharometer to ferment to 4° to 5° Balling. Formerly, the fermentation was allowed to proceed for about ten to fourteen hours only, but with the greater sugar content customary to-day, the fermenting period is usually fifteen to twenty hours. It is true that the fermentation must not be carried to the complete decomposition of the fermentable substances; for, on the one hand, the mother yeast must be removed at a point when the yeast is at the height of its development, and, on the other hand, the yeast must under no circumstances be allowed to progress to a point where it is weak and old when it is to be used. Therefore, up to the time of its use it must continue to ferment strongly. Every interruption, or rather arrestation, must be avoided in this regard. On the other hand, it is equally an error to use the yeast when it is too young. Delbrück is of the opinion that the yeast should be used when too old rather than when too young, as too young a yeast does not later possess the ability to reproduce itself actively when introduced into the mash, and this efficacy is a prime necessity. The yeast must become thoroughly ripe in the yeast mash, and a ripe, fully developed yeast only possesses the reproducing efficacy and fermentative power necessary in the chief mash. Unripe yeast is in a luxurious, straggly condition, and produces foaming fermentation, while ripe yeast is in a robust mature state, and produces smooth though vigorous and enduring fermentation. The ripened condition of the yeast is reached when the fermentation has advanced to about 4° to 5° Balling.

VIII.—REMOVAL OF THE MOTHER YEAST.

About one or two hours before the state of complete ripeness is reached, the mother yeast is removed from the yeast mash, and is introduced into a copper vessel. As the enzymotic condition is constantly undergoing changes, the vessel is placed in water as cold as can be obtained, in order by an effective cooling to favor as far as possible the development of the fermentation-exciting enzyme, zymase. A mother yeast of approved quality can often be kept from one year to another if enclosed in metal vessels, and kept on ice and properly disinfected. Such mother yeast is used from year to year at the commencement of each season. A yeast of this character, with rational development and normal preparation, usually retains a uniform efficacy. Lately, however, the opinion has been gaining ground, that it is of greater advantage not to store up the mother yeast for longer periods, but instead to conduct the yeast preparation in such a manner that, at the time when the yeast has fully ripened in a yeast mash, the next yeast mash is exactly at that point where it can be set with yeast from the ripened mash. In this manner are best avoided the dangers which are connected with the preservation of the mother yeast. The quantity of the mother yeast used is generally about 1/5 to 1/6 of the total yeast mash. Upon the quantity of the mother yeast depends the number of the newly formed cells, as well as the character of the yeast to be developed. A small quantity of mother yeast produces young yeast, while a large quantity tends to accelerate the aging of the cells; in the first case, a luxurious yeast, and in the latter, a robust yeast are obtained. If, however, it is the intention of the distiller to preserve the mother yeast, the operation should be carried out in special vessels of tinned sheet iron, provided with well fitting lids and placed in cold water not exceeding a maximum temperature of 54.5° F. It is preferable to keep the yeast in vessels mounted on pedestals and provided with annular lids, the rims of which extend beyond the edge of the vessels below the surface of the cooling water in which they are placed. In this manner the air with its attending dangers of infection is excluded. For preserving mother yeast for a longer period, Maercker recommends drying slowly at 111° F. The dried yeast is kept in air tight metal vessels upon ice, with the addition of cane sugar, charcoal, etc., to the semi-moist yeast mass. Reinke has devised an excellent method for the preservation of yeast, which prevents its infection during the process of preparation for preservation. The yeast is wrapped in thoroughly sterilized blotting paper, and is freed from water in presses, between asbestos plates, which, of course, are also sterile. The operation is carried out in a cold current of air previously sterilized and dried by means of concentrated sulphuric acid. In this way the packages of yeast are almost completely dehydrated. The preparation should be conducted in a room free from dust, which has been sprinkled with water. When the yeast cakes or packages have been dehydrated they are embedded in cold sterilized plaster of Paris in tin boxes which are soldered down when filled. The plaster of Paris absorbs whatever moisture remains, and forms a tight cover. By this method infection is absolutely precluded, and the yeast may be kept for years without injury.

IX.—THE USE OF RIPE YEAST FOR PITCHING THE SWEET MASH.

The ripe yeast should be added to the sweet mash at a temperature such that energetic propagation can at once set in—that is, at a temperature of about 86° F. If preparatory mashing vats with water cooling are available, and also if the distillery is provided with cool beds, the pitching operation is a simple one. Only where the process is carried out with special cooling apparatus, can the yeast be added directly to the fully cooled mash in the fermenting vat, and this mode of working is considered less advantageous than the other. It was formerly customary to freshen or revive the yeast with sweet mash before it was introduced into the chief mash, in order to induce further growth of the yeast through the addition of new substances capable of fermentation, thus obtaining a more vigorous fermentation. The further growth of the yeast is due to the dilution effected by the sweet mash. To-day, as the yeast is kept in lively fermentation until the end, and as further propagation is impossible because of the high alcohol content, the pitching of the yeast with sweet mash must be regarded as unnecessary and superfluous. As the yeast is protected from infection by a high degree of acidity in the yeast mash the freshening may really be regarded as a dangerous operation, as it dilutes the acid in the mash.

X.—SPECIAL DIRECTIONS FOR YEAST PREPARATION.

The preparation of yeast from pure green malt has been abandoned, for a material of sufficient concentration cannot be prepared with it. Neither is the employment of spent wash yeast to be recommended, according to the methods in use at present in the distillation industry. But under certain conditions it may be advisable to add a small quantity of spent wash in place of mashing water, for the purpose of increasing the sourness or acidity of the yeast material. In the preparation of the yeast, dead periods, that is, intervals during which infection by inimical organisms can occur, should be avoided. This is of special importance with the modern use of pure yeast cultures, for during intervals in the preparation there is the ever present danger of spontaneous sowing of wild yeast races from the air.

For each 100 gallons of capacity of the yeast vessel, about 50 gallons of sweet mash and 22 pounds of green malt are mashed together, the sweet mash being freed from husks by means of a sieve. The yeast mash is allowed to stand at 144° F. for about two hours for the purpose of saccharization. After this the mash is cooled to 133° to 135° F. by repeated stirring with the mashing oar, while at the same time 1 to 2 gallons of sour yeast mash, or the contents of a flask of pure lactic acid culture are added. The mash is allowed to stand but is carefully watched that the temperature may at no time fall below 122° F., until the desired degree of acidity, at least 2½°, though possibly 3°, is attained. To prevent excessive fall of temperature the steam mashing oar is used when necessary. After this, the yeast cooler, which should preferably be movable, is introduced into the vessel, and the mash is rapidly cooled to 86° F., in about twenty minutes; the mother yeast, or the ripe yeast from the previous yeast preparation is then added, and the cooling is allowed to progress to the desired pitching temperature. The temperature of the yeast now rises to 79° to 83° F.; it should ferment to 4° to 6° by saccharometer. If the yeast has stood for a longer period than originally intended, because of interruptions in the operation or for other reasons, it should not be pitched with sweet mash, but, instead, soured mash should be used for this purpose.

Another method is carried out as follows: 150 gallons of fresh, sweet, potato mash, freed from husks, 176 pounds of barley malt and 264 pounds of water at about 158° F. are used in the preparation of the yeast mash. The malt, which should be double-crushed, is thoroughly mashed with water, and to it is then added the cleared sweet mash, which is thoroughly mingled with the malt milk. After the completion of the mashing, the temperature should be about 144° to 146° F. The yeast mash is allowed to stand at this temperature for about two hours, and is then cooled to 126° to 129° F., at which temperature the acid formation takes place. After the completion of the souring and the removal of the mother acid, the mash is again warmed, and is allowed to stand for about half an hour at 167° F. After this it is cooled to the pitching temperature, and is set with mother yeast. The pitching should not be carried out before the yeast mash has been properly cooled to the necessary pitching temperature. In about twenty hours the temperature will have risen to 86° F., and the sugar will have been fermented to about 5° by saccharometer. After this the mother yeast can be removed. The yeast is added to the mash in the preparatory mash vat at 86° F., without being previously set with sweet mash.

XI.—THE INVESTIGATION OF THE YEAST.

The following determinations must be made with regard to the character of the yeast:

1. *The Determination of the Degree of the Fermentation.*—This is carried out in the usual manner with the aid of the saccharometer and a yeast filtrate. The saccharometer reading obtained from the filtrate of the sour yeast mash is compared with that obtained from ripe yeast. As has been stated above, yeast in a condition of ripeness should be fermented to 4° to 5° Balling.

2. *The Determination of the Acidity.*—Since we have learned that pure lactic acid fermentation, accompanied by the accumulation of acid, is the most important phase in the preparation of the yeast as regards the protection of the yeast mash against infection, the determination of the acidity of each yeast mash seems indispensable. The titration apparatus illustrated on page 193, and supplied

in this form in Germany by the Association of Spirit Manufacturers, is used for the purpose.

The yeast mash to be investigated is first filtered through a filter sack, and 20 cubic centimeters of this filtrate are taken up with pipette and allowed to flow into the cup *d*. Standard soda solution (corresponding to 31 grammes of soda in the liter) is drawn from the burette, which is graduated in cubic centimeters, and is allowed to mix with the filtrate, which is constantly stirred, until a drop of the mixture taken up on a glass rod and allowed to fall on a strip of litmus paper produces no red discoloration, but just begins to tinge the paper blue. The quantity of soda solution in cubic centimeters corresponds to the acidity in degrees. As mentioned before the yeast mash should possess a final acidity of 2.5° to 3°. The acidity of the sour yeast mash, as well as that of the ripe yeast, should be determined, and the two results should correspond approximately; the acidity of the ripe yeast should at the most, be 0.1° to 0.2° higher than that of the other. This increase in acidity may also occur in pure yeast; if the increase is greater it is an indication of the presence of schizomycetes, and new pitching yeast should at once be provided.

PART X.

FERMENTATION IN PRACTICE.

I.—THE VARIOUS FERMENTING PERIODS.

THE fermentation induced in a mash by the yeast runs its course in three phases, characterized as: Pre-fermentation, chief fermentation, and after-fermentation.

1.—Pre-Fermentation.

Pre-fermentation is the period of yeast propagation; during this period sugar decomposition and carbonic acid development take place. The yeast in the mash must propagate very freely, as otherwise it cannot decompose all the sugar available. According to Hayduck, the yeast increases in the yeast mash in the proportion of 1:4.5, while in the chief mash the increase is in the proportion of 1:13. The most energetic yeast reproduction takes place at 77° to 86° F., and it would appear that a temperature approximating this should be maintained during pre-fermentation. This, however, would be a mistake; for at such temperatures the conditions are favorable to the development of fungi inimical to fermentation, and before the yeast could begin to develop strongly, with the setting in of active fermentation, such growths would arise and, in consequence, would injure the yield of the fermentation. For this reason it is necessary to maintain a lower temperature, though temperatures as low as they were formerly used for pitching, about 59° F., are not advisable, as the yeast propagation under these conditions is extremely slow. Furthermore, with the concentrated mashes customary to-day, the principles formerly in vogue are no longer applicable. These included: pitching at low temperature and slow pre-fermentation, gradual transition to the chief fermentation period, and warm after-fermentation. This method of operation is no longer regarded with favor because the yeast is unable to accomplish the necessary work with concentrated mashes in the same time as with attenuated mashes, and for this reason low pitching temperatures are no longer chosen. The only possible manner of completely fermenting the sugar in concentrated mashes is by shortening the processes, hastening the chief fermentation, and increasing the length of the after-fermentation. Thus, it is necessary to choose a higher temperature, and, in practice, the usual pitching temperatures for concentrated mashes lie between 63° and 70° F. At higher pitching temperature, naturally, the mash begins to heat more quickly, and to evidence stronger activity, so that the application of movable vat cooling becomes necessary. In certain special processes, the setting in of the chief fermenting period is hastened; this is done by heating the mash, permitting warm water to flow through the movable cooling coil of the vat cooling apparatus. The process devised by Hesse is of this character. As the increase of the yeast is most energetic at 86° F., it would appear advisable to add the yeast to the mash at this temperature, as under the circumstances favorable to the yeast development, which occur during the cooling of the mash, the spore-forming activity of the yeast can begin at an early point in the operation. The formation of yeast, according to Hayduck's investigations, is impeded or completely arrested with a 5 per cent content of alcohol.

2.—The Chief Fermentation.

The chief fermentation is accompanied by an energetic development of carbonic acid gas and heat, and constitutes the period during which the maltose is fermented, the content of sugar in the mash decreasing constantly. This can be accurately observed by means of the saccharometer, the temperature being noted at the same time. The most favorable degree of heat for the process of chief fermentation approximates 81.5° to 86° F. To maintain the temperature below this limit is impossible without artificial means. As the increase in heat in 22° to 24° concentrated mashes, approximates as a minimum 65° F., the temperature during the chief fermentation period, if the pitching temperature were 68° F., would approach 101° F., a degree of warmth at which the organisms injurious to fermentation would overcome the yeast; a part of the alcohol would be consumed by acetic acid fermentation and, worst of all, the fermentative efficacy of the yeast, which must remain unweakened for the process of after-fermentation, would be seriously diminished. Therefore, under no circumstances, must the temperature be allowed to rise above 86° F. The former opinion that injury of the fermentative efficacy of the yeast did not begin below 93° F. has been disproved by practical experience. The chief fermentation period lasts about twelve hours.

3.—The After-Fermentation.

The purpose of after-fermentation is to ferment the dextrins, which through the after-action of the diastase are gradually converted into maltose during the pre-fermentation and the chief fermentation, or even during the progress of the after-fermentation itself. The principal requirement for an active after-fermentation is, therefore, the preservation of the sugar-forming efficacy of the malt; for, otherwise, the dextrins, which are in themselves unfermentable, remain unaffected. After-fermentation lacks the violent character of the chief fermentation, but nevertheless, it too, is uniformly accompanied by an active carbonic acid development. According to Delbrück, the most favorable temperature for after-fermentation approximates 77° to 81.5° F., and these figures have been confirmed by practical experience. It is conducted at a somewhat lower temperature than chief fermentation, as it has been shown that under these circumstances it progresses more strongly and evenly to the very end than at higher temperatures, under which it easily becomes weakened. Under no circumstances should the temperature of the after-fermenting period be permitted to fall below 74° F. Should this be the case, the cooling must be counteracted by heating the room or by covering the vats.

II.—MOVABLE VAT COOLING.

Before the conditions most favorable to fermentation were recognized, it was believed to be sufficient to insure the uniform maintenance of a certain upper temperature limit during the process, and this permissible high temperature limit was assumed to be 93° to 95° F., which, as has been noted before, is to-day regarded as an error. Concentrated mashes of 25° to 26° Balling, which in fermentation heated through 68° to 72° F., had, therefore, to be pitched at 57° F., as a maximum, and according to our present views, the pitching temperature should really have been as low as 50° F. A temperature as low as this would have been detrimental to the yeast propagation, and, furthermore, it would have been impossible to attain it by reason of the attending technical difficulties. The choice of higher pitching temperatures necessitated artificial regulation of the fermenting temperatures, for instance, that introduced in the artificial cooling of the vats. At the present time the operation is so conducted that the mash is pitched at 63° to 68° F., and as soon as the chief fermentation period, with the consequent heating to 74° to 77° F., begins, care is taken to prevent the heating of the mash above 86° F., by introducing a cooler into the vat and permitting cold water to flow through its tubes. When the chief fermentation period is completed, the current of water in the cooler is decreased, and the cooling is stopped entirely when the desired temperature of 77° to 81° F. for the after-fermentation is reached. The appliances for vat cooling are similar in construction to the movable yeast coolers. The various systems differ particularly in the form of their cooling elements and in the manner of actuating them. Most efficient are those which travel up and down in the mash with a stroke approximating the height of the vat, so that the cooling coil, which lies in a horizontal plane, at the same time exerts a pumping action tending to remove the carbonic acid gas. The arrangement of the tubes of a cooler of this form is illustrated in Fig. 58. Coolers with centrifugal action, of the type illustrated in Fig. 59, have also been found effective in practice. The arrangement and method of operation of this cooling coil is as follows: Coinciding with the vertical center line of the vat is mounted a perpendicular tube, adapted to act as a shaft, which is provided at its upper end with a funnel and a driving pulley. The upper bearing is carried by an arm secured to the wall of the fermenting room and extending over the vat. About 4 inches above the bottom of the vat the tube has branches extend-

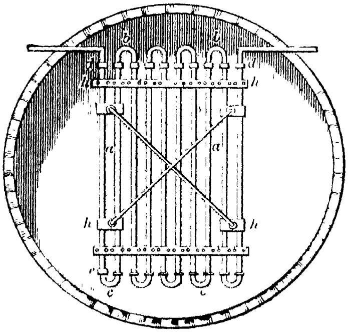

FIG. 58.—PLAN VIEW OF THE HESSE VAT COOLER.

ing upward and from one side to the other to form coils. The upper ends of the tubes constituting the coils are curved and discharge into a proper collecting vessel above the vat, which is provided with an outlet tube extending beyond the edge of the latter. The cooling coil is actuated by means of a belt transmission. The water used for cooling or heating is introduced into the funnel by means of a hose, and flows from the funnel through the coils and so into the collecting vessel and through the outlet of the same.

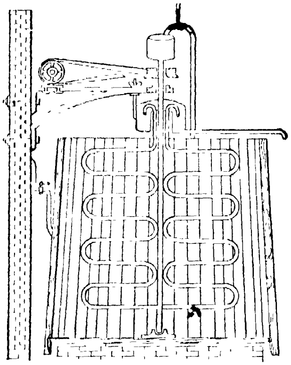

FIG. 59—KAMINSKI ROTATING VAT COOLER AND STIRRER.

The cooling coil is introduced into the vat before the latter is filled, and it remains in action until the completion of the chief fermentation period. For single operation two coolers are necessary, while four are required in double operation. The efficiency of this apparatus is high, according to investigations of Parow. The device is preferably driven, as in the case of the yeast cooler, by the motive power of the distillery. During the operation of the plant the main engine can be used for this purpose, and after the completion of the operation the cooler can be driven by a small special steam engine operated by the residual steam remaining in the boilers after the distillery shuts down.

Another form of movable cooler is shown in Fig. 60. This is actuated by a small steam engine, and can also be used for cooling the yeast mash.

The movable vat cooler must not only cool the mash, but it must furthermore keep the same in constant motion so that the carbonic acid retained by the mash may escape as rapidly as possible, in order to effect a saving in the space ordinarily requisite above the mash. With the assistance of vigorous agitation it is possible, also, to obtain healthier yeast and a greater yield. It may be assumed that with a vat volume of 1,000 gallons, the space above the mash is reduced 3.5 to 4.5 inches by means of vat cooling, and as 1 inch of this space corresponds to about 10 gallons of mash in a vat of the size mentioned, it is possible to increase the daily mashing capacity by about 50 gallons when vat cooling is employed.

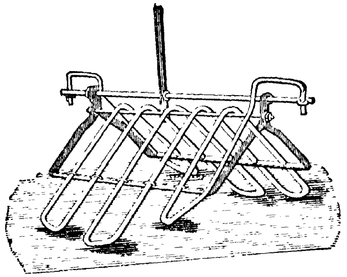

FIG. 60.—MOVABLE COOLER FOR FERMENTING OR YEAST VATS.

Energetic agitation and cooling result in better fermentation. The increase, according to Saare, approaches 0.9° saccharometer on an average. Altogether, it is thus possible by means of movable vat cooling to obtain an alcohol yield higher by about 0.6 to 0.7 per cent from the same vat capacity, and where the mashing volume is taxed, as in Germany, this saving is often a considerable one in the course of the year.

Should it be impossible, by reason of the failure of power, to operate the cooling apparatus during the night, when, under ordinary circumstances, the cooling is particularly necessary, it is advisable to employ Hesse's method, wherein cooling is necessary in the distillery during the regular operating period only. The vats are filled with mash, leaving about 2.4 to 3.2 inches of space above the mash, and a pitching temperature of 59° to 63° F. is chosen so as to avoid the necessity of cooling outside of the regular period of operation. As the mash heats very little under these circumstances, and the setting-in of the chief fermentation would normally be delayed considerably, warm water is introduced through the movable cooling coil, on the second day at a time when operation of the cooler is possible, until the mash is heated to 81° to 86° F. This heating requires one to two hours. The chief fermentation now begins with a strong development of heat, which would ordinarily far exceed the permissible limit of 86° F., and so the mash must be energetically cooled. After this the operation is concluded in the usual manner. This method proposed by Hesse has proven successful in practice.

On the whole, the advantages resulting from movable vat cooling are so great that this apparatus should be found in every distillery working with concentrated mashes. The initial expense of installation will be more than compensated for by economy in operation.

III.—CONCENTRATED MASHING AND ITS ADVANTAGES.

In Germany the mashing capacity is subject to taxation, and there the distiller always seeks to produce from potatoes mashes as concentrated as possible in order to obtain the greatest possible alcohol yield from the mashing capacity. Besides this, however, the entire progress of the fermentation is better in working with concentrated mashes than when attenuated mashes are used, for the losses due to by-fermentation and yeast formation are proportionately smaller. In order to prepare very concentrated mashes, condensation of the steam must be avoided as far as possible, by encasing the Henze apparatus, as well as all steam pipes, with material of low conductivity, by economical use of mashing water in the preparatory mash vat, by blowing out slowly in order to attain the highest possible evaporation during that operation, by freeing the mash with an efficient husk-removing apparatus, of the greater part of its ballast in order to render the mass fluid, and finally, by keeping the mash in lively motion during the chief fermentation period with the assistance of an effective movable vat cooler. By paying close attention to these requirements, it is now possible to obtain potato mashes registering at least 5°, and possibly even 6° to 7° Balling more than the starch percentage of the potatoes. According to Maercker, concentrated mashes ferment with greater purity than thin mashes, as the former yield as high as 12 per cent of alcohol, and the increasing alcohol content provides an excellent protection against the schizomycetes during the fermentation.

IV.—REVIVING THE MASH WITH WATER.

To ferment a concentrated mash completely it is necessary to add a certain quantity of water for the purpose of diluting the alcohol present toward the end of the fermentation. This is known as freshening or reviving, and it is unnecessary in attenuated mashes, but is extremely useful with thick mashes, as the alcohol content becomes so great in the latter that it finally causes the weakening of the fermentative action. The water should be added as soon as the condition of the mash toward the end of the chief fermentation period permits. The introduction of the water is furthermore convenient because by means of it the temperature of the mash can be suitably regulated for the after-fermentation. The quantity of water depends upon the vat space available above the mash. In Germany, in accordance with the prescriptions of the Tax Bureau, at least 1.6 inches of space above the mash must remain after the water is added.

V.—THE VALUE OF LONGER FERMENTATION PERIODS FOR CONCENTRATED MASHES.

In the fermenting period of seventy-two hours usually employed in the old methods of mashing with attenuated mashes, it was not difficult to ferment the mash to the final natural limit. To-day, however, the use of extremely concentrated mashes has become general, and it is often almost impossible for the yeast to act upon all the sugar present in the mash so that complete decomposition is effected in the same period. For these reasons, the government, in Germany, permits a prolongation of the fermenting period by twenty-four hours, making the total available time ninety-six hours. And, as a matter of fact, this regulation is thoroughly justified in working with concentrating mashes. It is said to be possible to shorten the fermenting period by providing the yeast with sufficient quantities of nitrogenous nutritive substances. According to Kusserow, this can be successfully accomplished by the addition of malt germs, which contain a large percentage of asparagin.

VI.—FOAMING FERMENTATION.

Foaming fermentation is the most unwelcome of all the forms of fermentation distinguished by the distiller. In this form of fermentation, the pitched mash develops such great quantities of foam and froth, from the time of the beginning of the chief fermenting period till the decreasing fermentation sets in, that a large part of the mash wells up and flows over the rim of the vat and is lost for the purposes of spirit manufacture. For a long time opinions regarding the causes of this phenomenon were at variance. Recent investigations resulting from a prize contest instituted by the Association of Spirit Manufacturers of Germany, have shown that foaming fermentation is a thoroughly good, extremely powerful form of fermentation, accompanied by the most active development of the yeast and its fermentative efficacy, which merely possesses the unpleasant property of excessive frothing due to the active propagation of the yeast, and that the ability to induce foaming fermentation is evidence of the superabundant power of the yeast. Only particularly effective yeast races are capable of exciting foaming fermentation. This form of fermentation, of course, can also result from conditions of exceptionally effective nutrition of the yeast. In consequence, it will not cause surprise that the excellent distilling Yeast Race II in many cases tends strongly to induce foaming fermentation. It was for this reason that at first the Race II was not rapidly introduced, notwithstanding its otherwise excellent characteristics. Meanwhile, we have become familiar with the nature of foaming fermentation, and in consequence, the following rules, as observed and laid down by Hesse, should be employed in counteracting its appearance:

1. Highly concentrated mashes, strongly soured, should be employed.

2. Thorough fermentation of the yeast to 4° to 6° by saccharometer, with a high final temperature of 86° F., in order to be able to introduce the strongest possible yeast into the mash, is advisable.

3. Only two-thirds to three-fourths of the usual permissible quantity of yeast should be used.

4. Pitching the yeast with sweet mash should be avoided. (These are all regulations whereby the yeast can be converted from the luxuriant condition, tending to propagate too freely, into a robust and healthy state.)

5. Long malt should be used.

6. Of this about 45.5 pounds only for each 1,000 gallons of mashing capacity should be used, and of this quantity about one-half or at most two-thirds should be saccharified in the preparatory mash vat, the remainder being intro-

duced after the completion of the saccharification in the fore-mashing vat, during the cooling and after the addition of the yeast at about 77° F. Furthermore, Hesse observed that foaming fermentation occurred during the chief fermenting period only. That is, at a time when an extraordinarily effective yeast was provided with practically unlimited quantities of sugar, if the saccharification with the entire quantity of the malt had progressed normally. If the yeast be supplied with less sugar, it does not induce such violent fermentation, and, consequently, forms little froth. It is for this reason that the malt is added in stages—first, that too much sugar may not be formed during the mashing, and secondly, that it may be gradually formed during the course of the fermentation in order to avoid foaming by providing insufficient quantities of sugar.

7. The mash must not be allowed to stand for too long a time for saccharization; after the blowing out the stirring apparatus is allowed to continue in operation for about ten minutes and cooling is thereupon at once begun.

If, in spite of these precautions, foaming fermentation nevertheless appears, it is customary to combat it by the use of petroleum, oil, or molten lard, which should be added to the mash as early as possible. As a rule, one-half to one-third of a quart of petroleum or fat for each vat is sufficient for the purpose, but the heaviest form of foaming fermentation cannot be overcome in this manner, nor is it possible to remove the cause thereby. For the rest, strong and long-continued steaming at high pressure, the maintenance of high mashing temperatures, the replacing of barley malt by rye or oat malt, as well as other precautions during the course of the operations, are often effective in overcoming this unpleasant form of fermentation. It is more certain, however, to follow the regulations given above as closely as possible, or to employ the

Yeast Race XII, which, in spite of strong fermentative efficacy, never induces foaming fermentation.

VII.—THE FERMENTING ROOM AND FERMENTING VATS.

The fermenting room should always, as far as possible, possess a uniform temperature—not too low in winter and not too high in summer. For this reason the fermenting room was often, in former times, located in the cellar. In the modern method of construction, however, the cellar space is usually reserved for the malting floor, and the fermenting room is consequently located on the ground floor. To insure the maintenance of proper temperatures the walls must be of at least two thicknesses of stone, and protection against temperature changes should be provided by limiting, as far as possible, the number of windows and doors. At times, heating apparatus, such as stoves or steam pipes, will be found necessary. However, this requirement is no longer so pressing, as it is far easier to-day to regulate the temperature by the introduction of vat cooling. If the fermenting room is cold, it is advisable to cover up the vats in any suitable manner after the completion of the chief fermentation period. Moreover, the water added after the completion of the chief fermentation also serves to regulate the temperature of the mash. Needless to say, the fermenting room should be kept absolutely clean, and to assist in maintaining this condition it should of course be provided with a proper water supply. When necessary, a powerful disinfectant, such as fluoric acid or chloride of lime, should be added to the cleansing water.

The fermenting room must, furthermore, be furnished with an unobstructed water outlet; it must be light so that it can be properly examined at all times to see whether every part of it is clean, and it should be of such height that the escaping carbonic acid from the fermenting vats cannot cause the fermenting mash to spurt to the ceiling. It must be so designed that movable vat cooling can be introduced without difficulty. A height of at least 12 feet between floor and ceiling is to be recommended.

It must be thoroughly ventilated in order to prevent the accumulation of too much carbonic acid in the air, but the ventilation must, under no circumstances, be allowed to cause drafts or irregularities in the temperature. For drawing off the carbonic acid several openings must be provided in the walls close to the floor; these openings lead to the outer air and can be closed by means of shutters to permit their regulation in any desired manner. The floor and walls of the fermenting room must be so constructed that, like those of the malting house, they can easily be washed or scrubbed. It is advisable to provide the walls to a height beyond the reach of the mash with a coating of asphalt tar, which should be applied hot several times to the thoroughly dry plaster or cement of the walls. For this purpose 2½ parts of asphalt to 2 parts of coal tar can be used. Concrete is best adapted for the foundation of the fermenting room as it can easily be cleaned. Asphalt is not as good as concrete for this purpose, as depressions are easily formed in it, in which the mash collects freely.

Fermenting vats are almost universally of wood, though for larger plants, in which vats of extreme dimensions are necessary, the latter are sometimes of iron. Occasionally vats of cement or sandstone plates are to be found, but these are hardly advisable, as they are attacked too easily by the sour mash. Fermenting vats of glass have been successfully experimented with, and have been found to possess valuable characteristics. However, it is extremely difficult to construct such large vessels of glass, and their consequent costliness has thus proved a serious hindrance to their general introduction. The wooden vats should be provided with a frequently repeated coating of oil paint, or as oil paint cannot stand scrubbing with lime, preferably with a durable varnish made from 4 pounds of colophony, ½ pound of shellac and 2 pounds of turpentine, dissolved in 1.8 gallons of 90 per cent spirit. The strength of the spirit should not be less than this, under any circumstances.

The vat is given one coating of this varnish and the varnish is then ignited. The coating burns into the vat and becomes very durable. The operation should be repeated a number of times before the vat is used. For purposes of cleansing, the vat should be coated regularly, after being emptied, with lime as freshly slaked as it can be obtained, and before the vat is used this coating of lime should be scrubbed out with water. Unused vats should be allowed to stand with the coating of lime and filled with water. Under ordinary circumstances the use of the lime is quite sufficient. If interruptions or retardations in the fermentation occur, the strongest methods must be at once applied, in order to destroy the inimical organisms, and among the best means for this purpose is sour sulphate of lime.

In distilleries working with concentrated mashes, vats of round or oval form are generally used, while in yeast distilleries square vats are not infrequently encountered. The latter require little room and render the removal of the yeast less difficult. The height of the vat depends upon the total content as well as upon the consideration of saving in space above the mash. The space above the mash is decreased if the vat is high. In general, the height of the vat should not be less than 39 or 40 inches. Vats having a volume of 750 gallons are usually 4 to 4 2/3 feet in height. The walls of the vat are usually 2 to 2.8 inches in thickness.

VIII.—WATER CONSUMPTION IN THE DISTILLERY.

The water consumption of the distillery depends chiefly upon the temperature of the available water, as the greater quantity of the water necessary is used for cooling purposes. With a water temperature of 50° F., it is possible to operate with but 3 to 4 gallons of water for each gallon of mash, while if the temperature is higher, the quantity of water requisite may be double this and even more. According to Goslich, the distillery well should be able to supply the following quantities of water, and the pump should have the corresponding capacity per hour, given below:

WATER CONSUMPTION OF THE DISTILLERY.

Content of the Fermenting Vats.	Daily Yield of the Well.				Capacity of the Pumps per Hour.
	Single.	Twofold.	Threefold.	Fourfold.	
	Operation.				
Gallons	Cubic feet.	Cubic feet.	Cubic feet.	Cubic feet	Cubic feet.
260	353.0	529.5	706.0	882.5	106.0
375	529.5	776.5	1059.0	1271.0	159.0
500	635.4	988.4	1271.0	1588.5	212.0
625	776.5	1200.0	1553.0	1765.0	265.0
750	918.0	1412.0	1765.0	2294.5	318.0
875	1059.0	1588.5	2118.0	2647.5	353.0
1,000	1235.5	1765.0	2471.0	3000.0	424.0
1,250	1588.5	2400.0	3177.0	3883.0	530.0

IX.—THE INVESTIGATION OF THE FERMENTED MASH.

1.—The Determination of the Degree of Fermentation.

One of the most important investigations for judging the excellence of the operations, is the determination of the degree of fermentation of the mash, when the latter is ready for distillation. For this purpose an average sample is taken from the vat after the contents have been thoroughly stirred, and the sample is filtered to complete clarity by means of the filtering apparatus. The mash should be protected against evaporation during the filtration process by proper encasing of the apparatus. The determination is carried out with the same saccharometer which is employed for the investigation of the sweet mash; but the results of the saccharometry with the sour mash are not merely compared with those of the sweet mash in order to ascertain the difference in the percentages, which represents the proportion of fermented sugar. On the one hand the saccharometer indicates not only the sugar percentage, but it shows as well, all the constituents of the raw substances which have been dissolved. That is, it represents the total extract; furthermore, there is also present in the fermented mash a substance of low specific gravity which makes the results of the saccharometry of the fermented mash appear too small. This substance is the alcohol which has been produced during fermentation. If the alcohol is not considered and, as is usual in practice, the saccharometer reading is taken direct from the fermented mash, the apparent fermentation only is determined, in contrast to the actual fermentation, which is found from the investigation of the filtrate which is deprived of its spirit content, and is then again brought to its original volume.

By taking into account the alcohol produced in the mash, it is possible to ascertain by calculation the number of saccharometer degrees by which the specific gravity of the filtrate has been altered through the influence of the alcohol. The following saccharometer degrees should be added to the saccharometer reading of the fermented mash at 17.5° C. or 63.5° F., in order to obtain the actual degree of fermentation:

Alcohol Content in Per Cent by Volume.	Saccharometer Degrees.
7	2.45
8	2.75
9	3.05
10	3.35
11	3.65
12	3.96
13	4.20
14	4.48

This table shows how largely the saccharometer reading is influenced by the alcohol content of the mash. For example, a thick mash of 24° is fermented to 1½° by saccharometer. What is the actual quantity of fermented substance? The apparent result of 1½° saccharometer should be increased by 3.95 with the 12 per cent by volume alcohol content of the mash, which is to be expected under these circumstances, so that the actual fermentation of the mash has progressed to 5.45 by saccharometer, and hence 24° - 5.45° = 18.55° by saccharometer have been fermented.

Foth has prepared a table which shows the alcohol content to be expected with various apparent degrees of fermentation (that is, the result of the saccharometer investigation with the fermented mash) of sweet mashes with definite saccharometer readings.

From this table we see that the generally accepted view that mashes of 26° by saccharometer need only be fermented to 3° to 4° by saccharometer in order to give the same yield as mashes of 20° by saccharometer, fermented to 1° to 1.5°, is wrong. The excess alcohol produced from mashes rich in sugar naturally decreases the saccharometer reading of the fermented mash proportionately more, so that according to Foth's table, if 20 per cent mashes show a fermentation of 1.3°, 25 per cent mashes with equal yield must show a saccharometer reading less by 0.45° only.

The opinion is still held very widely that it is unrea-

TABLE FOR DETERMINING THE APPARENT DEGREE OF FERMENTATION AND THE ALCOHOLIC CONTENT OF MASHES, OF WHICH 78 PER CENT OF THE EXTRACT IS FERMENTED SO THAT 1 POUND OF FERMENTED EXTRACT YIELDS 0.068 GALLON OF ALCOHOL

Saccharometer Reading of the Sweet Mash	Apparent Degree of Fermentation (= Saccharometer Reading of the Fermented Mash).	Alcohol Content of the Fermented Mash. Per Cent.
15	0.825	7.45
16	0.925	7.98
17	1.025	8.51
18	1.125	9.05
19	1.225	9.59
20	1.300	10.13
21	1.375	10.69
22	1.450	11.24
23	1.550	11.80
24	1.650	12.37
25	1.750	12.94
26	1.850	13.52
27	1.950	14.09
28	2.075	14.68
29	2.175	15.26
30	2.300	15.86

sonable to work concentrated mashes because they do not ferment sufficiently; this view must be considered erroneous. High percentage mashes can be fermented just as far as those of low percentage. If the highly concentrated mash is produced from potatoes rich in starch, so that the extract contains a large content of fermentable sugar and a small percentage of other constituents, the high percentage mash, in which the proportion of alcohol produced is large, may show a far better fermentation than a low percentage mash, which is poor in sugar and in which the quantity of alcohol present is small. The actual fermentation, therefore, is not always poorer in the mashes of the latter kind. Thus, for instance, a mash containing 9 per cent of alcohol by volume, and having an apparent fermentation of 2.4°, possesses the same actual fermentation of 5.45° as a mash containing 13 per cent of alcohol, and having an apparent fermentation of 1.3°; this fact should not be neglected in judging the excellence of the operations in question. In this regard, conclusions should never be drawn from the results of the saccharometric investigation without due consideration to the circumstances under which the investigations were made.

2.—The Determination of the Acidity.

The determination of the acidity is carried out with 20 cubic centimeters of the clear liquid from the fermented mash, by means of the known titration apparatus, illustrated on page 193. But the determination of the acidity of the fermented mash is not conclusive; it determines the increase only in acidity, which has occurred during fermentation. We have seen above that the sweet mash itself is sour, and that the degree of the acidity varies between comparatively wide limits. With regard to the character of the operations, the investigation thus shows the increase in acidity alone, that is, the difference between the quantity of acid in the fermented mash and that of the sweet mash. The smaller the increase is, the purer has been the fermentation, and the better, in general, has been the work of the distiller; the greater the original quantity of acid in the yeast, and the stronger the action of the lactic acid ferment of the yeast, the smaller will be the increase in acid of the mash, for greater quantities of acid suppress the acid-forming fungi. An increase in acidity of 0.1 to 0.2 cubic centimeter may be regarded as excellent, 0.2 to 0.3 cubic centimeter as satisfactory, while more than 0.3 must be characterized as poor. In the last case it is absolutely necessary to procure new lactic acid cultures, and to watch the operations in the preparation of the yeast and in mashing with the greatest care.

3.—The Determination of the Alcohol Content of the Fermented Mash.

The determination of the alcohol content constitutes the most reliable expression of the success of the entire distilling process. It is for this reason that the alcohol determination should always be made, in every properly conducted distillery. For the purposes of the investigation 100 cubic centimeters of the fermented mash filtrate are placed in a liter flask and diluted with the same quantity of water; the mixture is boiled until all the alcohol has distilled over. It is certain that this has been accomplished when the distillate has been brought to the original volume of 100 cubic centimeters. The liquid which has been made up exactly to the 100 cubic centimeter mark of the flask, is shaken, and is then placed in a dry glass cylinder, is cooled to the normal temperature of 15.5° C. or 60° F., and is tested for its alcohol content by means of a hydrometer, known specifically as a low wine testing device. The glass factory of the Association of Spirit Manufacturers of Germany provides especially delicate hydrometers for this purpose. They are graduated to 1/5 of a per cent to insure accurate readings. The complete testing apparatus, which can be procured from the same institution, is illustrated in Fig. 61.

This can also be used for the examination of the wash with regard to its alcohol content. As in the wash it is usually a question of a few tenths of a per cent of alcohol, 500 cubic centimeters of the filtered wash are examined. The distillation is carried out as in the examination of the mash, and the test sample is boiled until the prepared 100 cubic centimeter flask is filled exactly to the mark. As the quantity of alcohol contained in the

500 cubic centimeters of wash has thus been reduced to 1/5, the reading of the hydrometer must be divided by 5. In practice the distillation method is the only really useful determination, although there are other reliable methods of examination for laboratory determination.

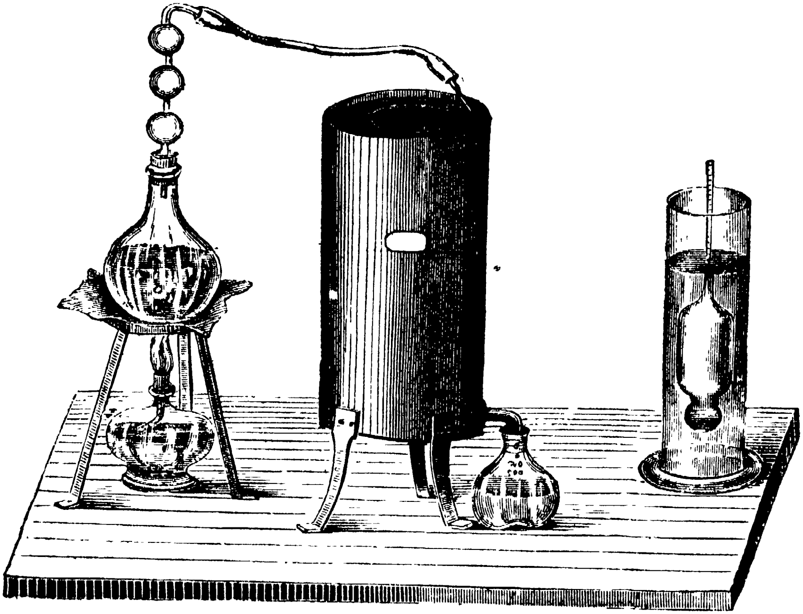

FIG. 61.—APPARATUS FOR THE DETERMINATION OF THE ALCOHOL CONTENT OF THE MASH.

X.—THE ALCOHOL YIELD OBTAINED IN PRACTICE.

During the operations of spirit manufacture certain losses take place. These are as follows:

1. Certain quantities of starch remain undisintegrated; it is true that with the steaming apparatus in use to-day

this loss is a small one, but, nevertheless, it must be considered to aggregate 1 to 2 per cent of the mashed starch.

2. Certain quantities of the fermentable substances dissolved by the malt, remain unfermented. These quantities in the best methods of operation, constitute 4 per cent of the fermentable substances, with average operation 7 per cent, and with unsatisfactory operation 12 per cent.

3. All the sugar which is fermented is not split up into alcohol and carbonic acid; certain unavoidable by-products of the fermentation also arise. About 5 per cent of the sugar is, on an average, converted into succinic acid, glycerine, and other metabolic products, and is used for the nourishing of the yeast. From 7 to 12 per cent is lost through impure fermentation.

4. During the course of the fermentation certain quantities of the alcohol are evaporated.

5. Certain quantities of the carbohydrates are consumed through by-fermentation.

6. A certain part of the alcohol is transformed into acetic acid and aldehyde. Accordingly, it can be assumed that from 100 parts of mashed starch 10 to 16 per cent is lost even with the best methods of operation, 19 per cent with average methods, and 27.8 per cent with unsatisfactory operation.

As a rule, it may be assumed that of the total quantity of carbohydrates present in the mashing raw material, 88 per cent is converted into alcohol with the best methods of operation, 80 per cent with average operation; and 72.5 per cent with unsatisfactory methods. In accordance with these figures, the alcohol obtainable from 1 pound of starch in very rare cases is .069 to .071 gallon, with excellent operation .068 to .069, with average operation .065 to .066, and with unsatisfactory operation .059 to .060.

Therefore, it is not asking too much to require that an expert distiller should produce at least .065 gallon of alcohol for each pound of starch in the mashing raw materials (potatoes and malt). If the distillery is provided with the best apparatus, and if the distiller understands his business, he will be able to obtain .068 gallon and even more from each pound of starch. However, as has been mentioned before, this yield can only be expected under favorable conditions.

XI.—THE AMYLO PROCESS.

For some time past mixtures of fungi have been used in Japan and China for the production of beer and vinous drinks. Of these fungi certain schizomycetes possess the characteristic, in developing, of forming enzymes which convert gelatinized or liquefied starch into sugar, similarly as in the diastatic action of the malt. Certain of these fungi under definite culture conditions are further capable of splitting up sugar into alcohol and carbonic acid. Calmette isolated from the mixture of fungi a series possessing this efficacy, and he characterized them as *Amylomyces Rouxii*. The Japanese chemist Takamine was among the first to investigate these fungi and to effect the technical introduction of the fungus process; the methods devised by him are covered by numbers of patents in various countries. Recently, these methods of using mold fungi, based upon the investigations of Calmette and Boidin, have been introduced on a large scale in practical distilleries. The operations here too are carried out upon the principles of the absolute pure culture, so that thoroughly sterile mashes are saccharified with absolutely pure cultures of the *Amylomyces* and are finally fermented with yeast. Up to the present time, the methods have been limited to the working of corn mashes.

The operation, which is carried out with the observance of the strictest rules of sterilization of all the apparatus in question, is substantially as follows: The corn is steamed in the Henze apparatus in the usual manner, is blown out into the mashing vat, and then, with the use of only 1 to 2 per cent of barley in the form of malt, is mashed in the ordinary manner. The malt is used for the purpose merely of liquefying the starch and rendering the mash fluid and capable of being pumped. It is not a question of complete saccharification, though this would, of course, be useful. After the completion of the mashing, the entire mass in the vat is heated to the boiling point, after a small quantity of sulphuric acid has been added, and in this condition the mash is pumped into the fermenting vat, and either in this vessel, or in a horizontal steamer, it is sterilized at a pressure of 1½ atmospheres. The quantity of the added sulphuric acid depends upon the amount of carbonate of lime in the mashing water. The fermenting vat is a cylindrical iron vessel, which can be tightly closed, and for this purpose is provided with the most efficient appliances in order to hinder the entrance into the mash of fungi inimical to fermentation. First, the mash is maintained at the boiling point for a considerable time in this vat, in order to sterilize it completely, and then the cooling is begun by external sluicing of the iron vessel, the strong stirring apparatus within the vat being kept in constant operation, while a current of cold, purified air, absolutely free from fungi, is blown through the vat. When a temperature of 101° F. is reached, the mash is infected with the fungus. The pure cultivation of the latter is carried out with cooked rice, which covers the bottom of a flask of about 1 quart capacity. The rice, together with the fungi, is washed into the fermenting vat with the necessary precautions usual in bacteriological work. The small quantity of 1 gallon is sufficient for 100,000 gallons of the mash. The stirring apparatus is kept in operation and sterilized air is continuously blown into the vat; the fungus begins to form long threads and in twenty-four hours completely pervades the mash. The iodine reaction becomes weaker from hour to hour; the fungus is now in full sugar-forming activity. Subsequently, the fungus threads separate into individual barrel-shaped branches, and alcoholic fermentation sets in, accompanied by the development of carbonic acid. The fermentation however is slow, and the fungus is, therefore, so little suited for the working of concentrated mashes that its fermentation-exciting power must be increased by the addition of pure culture yeast. Before pitching with yeast the mash is cooled to 86° F., and when this point is reached it is infected from a Pasteur flask with about one-half gallon of liquid yeast containing barely 0.2 ounce of solid yeast, for the tremendous mass of 100,000 gallons of mashed material. This slight quantity is sufficient to permeate the entire mass with yeast within twenty-four hours, and with continued introduction of air, to induce vigorous fermentation. For this purpose the Yeast Races II and XII have proven most effective. The mold fungus does not injure the yeast, though probably the latter is inimical to the former, so that the growth of the mold fungus should be nearly completed before the yeast is added. Several hours after the yeast is introduced, the air is shut off, the stirring apparatus is continued in operation, and the simultaneous action of the two fungi begins. This leads to the completion of the fermentation in a further period of seventy-two hours, the fermentation being carried to 0, or even less. The total time of the operation in the fermenting vat comprises five times twenty-four hours; thus, if the day for the mashing and emptying is included, the fermentation period lasts six days. The spirit produced is distilled with the usual apparatus, and it is said to possess a high degree of purity. With careful and conscientious operation this process yields 0.078 gallon of alcohol for each pound of starch; or, for each pound of corn containing 60 per cent of starch, the yield is 0.047 gallon of alcohol, whereas with the old methods it was possible to obtain but 0.040 gallon under the most favorable circumstances. The feasibility of this process and its advantages for very large plants must be regarded as proven; it is still an open question, however, whether its introduction for operation on a smaller scale is practicable. The installation requires great outlay, the operation is expensive, the coal consumption is high, interruptions—easier to avoid in working on a large than on a small scale—cannot apparently be avoided, and finally, the value of the resulting wash is less. The process has so far been proven of value for the working of corn only.

To test its utility for the working of potatoes, thorough investigations were carried out, at the instance of Delbrück, by the Institute for Fermentation Industries, of Germany, and from these it would appear that the application of the amylo process to potato distillation is, at the present time, apparently unpromising.

PART XI.

DISTILLATION AND RECTIFICATION.

I.—GENERAL INFORMATION.

THE fermented mash contains the alcohol accompanied by water, unfermented sugar, husks, salt, yeast, and volatile and non-volatile by-products of fermentation. The separation of the alcohol from the water of the fermented mash by means of distillation, and the condensation of the distillate, are possible because the former possesses a lower boiling point than water; the latter, as is known, boils at 212° F., while the boiling point of absolute alcohol is approximately 173° F. If a mash, which under modern circumstances contains from 10 to 12 per cent of alcohol, is brought to the boiling point, the volatilization of the alcohol is not such that the total alcohol distills over as absolute alcohol, that is, in a dehydrated condition, at 173° F., while the water remains unevaporated until 212° F. is reached; but each mixture of alcohol and water possesses a certain definite boiling point, also called the distillation point, which varies with the alcohol content, the lower the alcohol percentage, the higher being the boiling point.

The following table, compiled by Groening and amplified by Doenitz gives the boiling points of alcoholic liquids of various strengths, as well as the alcohol content of the vapor resulting from their ebullition.

According to the investigations of Sorel, the figures given in Groening's table vary somewhat from the results in practical experience, in which the construction and capacity of distilling apparatus are taken into consideration. Sorel's table, given herewith, was compiled in ac-

Boiling Temperature in degrees F.	Content of Alcohol.				Boiling Temperature in degrees F.	Content of Alcohol.			
	Of the Fluid.		Of the Vapor.			Of the Fluid.		Of the Vapor.	
	Percent. by Volume.	Percent. by Weight.	Percent. by Volume	Percent by Weight.		Percent. by Volume.	Percent. by Weight.	Percent. by Volume.	Percent. by Weight.
210.2	1.0	0.8	13.0	10.5	182.0	46.0	38.8	84.1	78.4
208.7	2.0	1.6	28.6	23.5	181.6	47.0	39.7	84.3	78.7
207.2	3.0	2.4	35.0	29.0	181.4	48.0	40.7	84.6	79.0
206.0	4.0	3.2	39.9	33.3	181.2	49.0	41.6	84.8	79.3
204.6	5.0	4.0	43.4	36.5	181.1	50.0	42.5	85.1	79.6
203.4	6.0	4.8	46.7	39.5	181.0	51.0	43.5	85.3	79.9
202.1	7.0	5.6	49.8	42.3	180.7	52.0	44.4	85.5	80.2
201.0	8.0	6.4	52.3	44.7	180.5	53.0	45.4	85.7	80.4
200.0	9.0	7.2	54.5	46.8	180.3	54.0	46.3	86.0	80.7
198.7	10.0	8.0	57.2	49.4	180.1	55.0	47.3	86.2	81.0
197.8	11.0	8.9	59.0	51.2	179.8	56.0	48.3	86.4	81.2
196.7	12.0	9.7	60.8	53.0	179.6	57.0	49.2	86.6	81.5
196.0	13.0	10.5	62.1	54.6	179.4	58.0	50.2	86.9	81.8
195.1	14.0	11.3	64.0	56.2	179.3	59.0	51.2	87.1	82.0
194.4	15.0	12.2	65.4	57.7	179.1	60.0	52.2	87.3	82.3
193.5	16.0	13.0	66.8	59.1	179.0	61.0	53.2	87.5	82.5
192.7	17.0	13.8	68.0	60.4	178.7	62.0	54.2	87.6	82.7
192.2	18.0	14.6	69.2	61.6	178.5	63.0	55.2	87.8	83.0
191.5	19.0	15.4	70.3	62.8	178.3	64.0	56.2	88.0	83.2
191.0	20.0	16.3	71.3	63.9	178.1	65.0	57.3	88.2	83.4
190.2	21.0	17.1	72.1	64.8	178.1	66.0	58.3	88.3	83.6
190.0	22.0	17.9	73.0	65.7	178.0	67.0	59.3	88.5	83.8
189.3	23.0	18.8	73.7	66.5	177.8	68.0	60.4	88.6	84.0
188.8	24.0	19.6	74.4	67.3	177.6	69.0	61.4	88.8	84.2
188.5	25.0	20.5	75.1	68.1	177.4	70.0	62.5	89.0	84.4
188.0	26.0	21.3	75.8	68.8	177.3	71.0	63.6	89.1	84.6
187.5	27.0	22.1	76.4	69.5	177.1	72.0	64.6	89.3	84.8
187.2	28.0	23.0	77.0	70.2	177.0	73.0	65.7	89.4	85.0
186.8	29.0	23.8	77.6	70.8	177.0	74.0	66.8	89.5	85.2
186.3	30.0	24.7	78.1	71.4	176.7	75.0	67.9	89.8	85.5
186.0	31.0	25.6	78.7	72.1	176.6	76.0	69.0	90.0	85.7
185.4	32.0	26.4	79.2	72.7	176.2	77.0	70.2	90.1	85.9
185.1	33.0	27.3	79.7	73.2	176.1	78.0	71.3	90.3	86.1
185.0	34.0	28.1	80.1	73.7	176.0	79.0	72.5	90.4	86.3
184.6	35.0	29.0	80.5	74.1	175.8	80.0	73.6	90.6	86.6
184.4	36.0	29.9	80.9	74.6	175.6	81.0	74.8	90.8	86.8
184.1	37.0	30.7	81.2	75.0	175.5	82.0	75.9	91.0	87.0
184.0	38.0	31.6	81.6	75.5	175.5	83.0	77.1	91.1	87.2
183.6	39.0	32.5	82.0	75.9	175.3	84.0	78.3	91.3	87.4
183.4	40.0	33.4	82.3	76.3	175.1	85.0	79.5	91.5	87.7
183.1	41.0	34.3	82.7	76.7	174.9	86.0	80.7	91.6	87.9
183.0	42.0	35.2	83.0	77.1	174.7	87.0	82.0	91.8	88.1
182.7	43.0	36.1	83.3	77.4	174.6	88.0	83.2	92.1	88.5
182.3	44.0	37.0	83.6	77.8	174.6	89.0	84.5	92.3	88.8
182.1	45.0	37.9	83.8	78.1	174.4	90.0	85.8	92.6	89.2

cordance with his observations, in which he subjected Groening's figures to a critical examination and found that they were somewhat too high, especially for lesser strengths of alcohol. This is probably due to the fact that there is a condensation of weaker alcoholic fluid on the walls of the distilling vessels, which renders the determination of the content of alcohol in the vapors or distillates too high.

GROENING'S TABLE AS CORRECTED BY SOREL.

Content of Alcohol in the Boiling Fluid. Per cent. by Volume.	Content of Alcohol in the Vapors Evolved, According to Groening. Per cent. by Volume.	Content of Alcohol in the Vapors Evolved, According to Sorel. Per cent. by Volume.	Difference. Per cent. by Volume.
0	0	0	0
5	43.4	35.75	7.65
10	57.2	51.00	6.20
15	65.4	61.50	3.90
20	71.3	66.20	5.10
25	75.1	67.95	7.15
30	78.1	69.26	8.84
35	80.5	70.60	9.90
40	82.3	71.95	10.35
45	83.8	73.45	10.35
50	85.1	74.95	10.15
55	86.2	76.54	9.66
60	87.3	78.17	9.13
65	88.2	79.92	8.28
70	89.0	81.85	7.15
75	89.8	84.10	5.70
80	90.6	86.49	4.11
85	91.5	89.05	2.45
90	92.6	91.80	0.80
95	95.4	95.05	0.35
97.6	97.6	97.60	0.00

From Groening's table we see, for instance, that from a 12 per cent alcoholic mash, which boils at 196.7° F., vapors are first evolved which contain 60.8 per cent by volume of alcohol. Because at the beginning of the ebullition vapors very rich in alcohol are formed, the alcohol content of the boiling liquid naturally, at once begins to decrease, and when, for instance, it has fallen to 10 per cent, the boiling point rises to 198.7° F., the alcohol content of the vapors falling to 57.2 per cent. If through the distillation of the alcohol the content of spirit in the remaining mash has fallen to 5 per cent, the alcohol content of the steam is 42 per cent only, and this decrease continues until all the alcohol is distilled off. From this it appears that while absolute alcohol cannot be obtained through the distillation of an alcoholic mash, nevertheless, the total alcohol vaporizes before the water does, so that it is possible to obtain from an alcoholic mash a distillate with an alcohol content higher than that of the original mash.

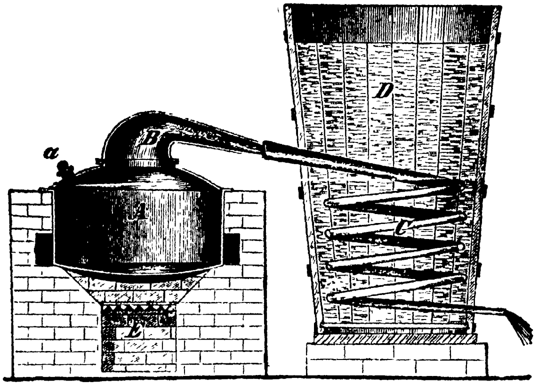

FIG. 62.—SIMPLE DISTILLING APPARATUS.

II.—SIMPLE DISTILLATION.

The oldest method of strengthening alcohol consists in redistilling the condensed alcohol as frequently as possible. The latter is stronger than the mash, but still not of sufficient strength for use. In this method, after each repeated operation, a stronger distillate is obtained, while a watery residue remains which is free from alcohol. Naturally, the process is an extremely complicated one, but it remained the only available method for hundreds of years. Fig. 62 shows apparatus available for distillation as carried out in the old, simple distilleries; it comprises essentially, an alembic or still combined with a cooler. Through the opening *a*, the mash to be distilled is introduced into the still *A*, the head *B* is placed upon the still and the mash is heated to the boiling point by direct application of fire at *E*. The evolved vapors enter the worm *C*, which is located in the cooling water vessel *D*, and are here condensed. The distillates from several stills are combined and returned to the still *A* for redistillation, and this operation is repeated until alcohol of the desired strength is obtained.

III.—DEPHLEGMATION.

The principle of the dephlegmator consists in the partial condensation of the alcoholic vapors from the still or rectifier, and the consequent enrichment of these vapors. According to Pampe, the vapors are not separated into poorer and richer portions in the dephlegmator, those poorer in alcohol being condensed, but the vapors are uniformly condensed as in the rectifier, and by the action of the succeeding vapor the condensed fluid is again volatilized. In simple distillation, on the other hand, it will be remembered, alcohol is strengthened in exact accordance with the figures of Groening's table as corrected by Sorel. From this it would appear that the strengthening action of the dephlegmator is due to frequently repeated condensation by cooling and re-evaporation accompanied by concentration.

According to Pampe the following rules should be observed in the operation of the dephlegmator: First, the vapors should move slowly through the device; secondly, the cooling should be gradual—that is, the difference in temperature between the cooling surface and the alcoholic vapor must not be too great; thirdly, as perfect as possible a counter-current of vapor and cooling water should obtain in the dephlegmator; and lastly, the separated fluid should move from a colder to a warmer portion, while a counter-current between the descending low wine and the ascending vapor should be maintained.

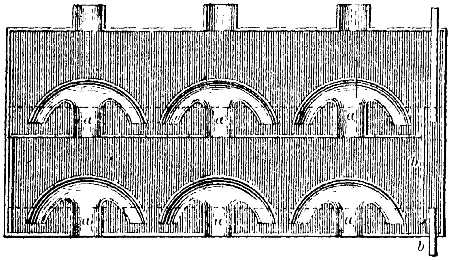

Fig. 63 —The Tube Rectifier.

Figs. 63 and 64 illustrate examples of tube and bell rectifiers, used for the concentration of vapors poor in alcohol to vapors richer in alcohol. Each comprises a plurality of low cylindrical chambers, the bottoms of which are connected by lateral pipes. Several short tubes are arranged on the bottom of each chamber projecting upward to a point above the top of the pipe at the side, so that the level of the fluid in the chamber is always lower than the tops of the short tubes. In the tube rectifier, the tubes branch off into two smaller downwardlydisposed tubes, with openings which discharge below the level of the fluid in the chamber. In the bell rectifier, metal bells are mounted over the short tubes with their edges below the level of the fluid. The vapors rising from the still are condensed in the lowest chamber and fill the bottom of the rectifier column and the chamber with fluid which gradually rises to the level of the lateral pipe, through which the low wine escapes back to the still. As the short tubes can discharge into the fluid in the chamber only, the succeeding vapors are forced to pass through the more concentrated solution, and are thereby enriched in alcohol. The fluid is eventually also evaporated and in the form of a vapor richer in alcohol than the first passes into the second cylinder, in which it is condensed, then into the third, and so on until the strongest concentration is obtained in the highest chamber.

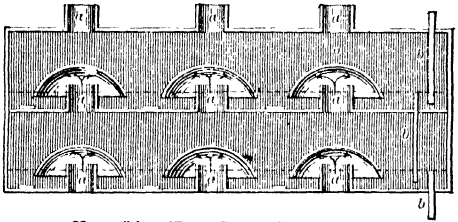

FIG. 64.—THE BELL RECTIFIER.

The rectifier columns in the latest forms of apparatus of this character are constructed so that the mash passes downward through the chambers, while steam enters in an opposite direction and passes through small tubes discharging below the surface of the liquid, and thus in its passage becomes enriched with alcohol, while the mash becomes thoroughly exhausted. In certain types of apparatus the escaping vapors pass through sieve bottoms or perforated partitions for the purpose of rectification. In one type of rectifier, Ilges's apparatus, the alcoholic vapors pass through cylinders filled with glass or porcelain balls.

The products of the distillation of the mash are, first, low wines obtained by simple distillation, spirits or whisky obtained by rectification, and alcohol obtained by compound distillation. Low wines contain as high as 40 per cent of alcohol, spirits between 40 and 55 per cent, and alcohol between 55.6 and 96.7 per cent. The residue after the distillation has freed the mash as far as possible from alcohol, is known as spent wash, and usually is of considerable value as food for cattle and for other purposes. From the above it will be seen that distillation can be carried out by two methods: First, by simple distillation, in which products of increasing strength are obtained by repeating the operation; and secondly, by compound distillation, in which the apparatus includes rectifiers or dephlegmators. Compound distillation apparatus is divided into two classes, comprising periodically-working apparatus and continuously-working apparatus, respectively.

IV.—COMPOUND DISTILLATION, RECTIFICATION AND DEPHLEGMATION.

1.—Periodic Distilling Apparatus.

The simple method described in section II above was, of course, available for the manufacture of spirit on a very small scale only. The arrangement of modern distilling apparatus is such that the alcoholic vapors from the mash pass into the rectifier column and from there into the dephlegmator or the condenser, where for purposes of strengthening them they are partially cooled and condensed. The liquid condensed in the dephlegmator flows back into the rectifier and there encounters the ascending current of weak alcoholic vapors. By the contact the vapors are brought to ebullition and evaporation, and become richer in alcohol. The apparatus is so devised that this operation is repeated until a very strong alcohol is obtained. It will be understood that the rectifier and dephlegmator are often interdependent. It was a great advance in the science of distillation when Pistorius in 1817 constructed an apparatus which, in one operation, effected the distillation and the strengthening of the alcohol. This was, of course, possible only by repeated condensation of the distillate and renewed vaporization of the alcohol. The Pistorius apparatus in its column form is illustrated in Fig. 65.

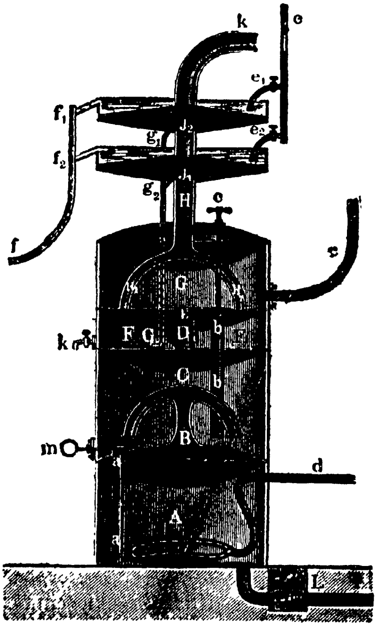

FIG. 65.—PISTORIUS'S COLUMN DISTILLING APPARATUS.

The device includes a pre-heater, which has a very favorable action in increasing the economy of the heat consumption. Furthermore, in this apparatus the mash was not deprived of spirit by direct firing, but lost its alcohol through heating by steam, and this too, was a decided advance in the art. The exhaust steam from the steam engine can be used for the operation of Pistorius's still. The mash, which is to be distilled, is first introduced through the pipe *c* into the pre-heater *G*, passed from *G* through the valve opening, which can be adjusted as desired at *c*, into the tube *bb*, and then into the upper still *C*, from whence it is passed through the valve *m* and the tube *aa* into the lower still *A*. Steam is introduced through the steam pipe *d* into the still *A*, and the mash is there completely deprived of spirit. Weak alcoholic vapors are thereby evolved, as the mash, as we shall see directly, has already been deprived of alcohol to a certain extent in the still *C*. The weak alcoholic vapors have a somewhat higher temperature, and pass through the tube *B*, which discharges through two curved arms under the surface of the mash in the still *C*, into the latter, where the contents are brought to ebullition and are partly deprived of spirit, as the temperature of the vapors is higher than the boiling point of this strongly alcoholic mash. The vapors which have been enriched with alcohol, then rise through the tube *D* into the low wine chamber *F*; the tube *D* for the introduction of steam is provided with a flanged cap so that the vapors rising from *C* must force their way through the contents of the chamber *F*, thereby bringing the liquid in the chamber to ebullition and vaporizing the alcohol it contains. The vapors evolved in the chamber *F* then rise through the double tube H_1 H_2 into the collecting tube *H*. In doing this they pass through the pre-heater *G*, warm the mash which this contains so that it afterward enters the still *C* in a pre-heated condition through the tube *b*. The vapors are partly condensed by this operation, flow back into the low wine chamber *F*, and are strengthened by repeated distillation in this manner. The strengthened alcohol vapors now pass through the tube *H* into the basins J_1 and J_2 of the apparatus. These lentil-shaped basins are provided with rims on their upper sides, and are thus adapted to receive layers of water. As indicated in the engraving, they have inserted cone-shaped covers, around which the alcohol vapors must pass so that they are cooled by contact with the surface cooled by the water, and thus a part of the alcohol condenses in a weaker condition, flows back through tubes g_1 and g_2 into the low wine chamber F to undergo redistillation and strengthening. From the first basin J_1 the vapors pass into the similar basin J_2 where they are again strengthened by being partly condensed, the condensed liquid passing through the tube g_1 to the tube g_2 and thus returning to the low wine chamber F. The vapors which are thus sufficiently strengthened then pass through the tubes h into the cooler, and are here condensed to strengthen the spirit. In this apparatus it is possible, by regulating the quantity and temperature of the cooling water used in the basins, to attain any degree of strength in the alcohol; by means of the Pistorius device it is possible to obtain spirit of high percentage. As can be seen from the above description, the operation of the apparatus is a periodic one that is, when the contents of the still A have been deprived of spirit, the still must be emptied by means of the cock L and the contents of the still C allowed to pass into A, while the contents of the pre-heater G are introduced into C. Consequently apparatus of this type requires constant care and attention, as, naturally, it must always be ascertained when the mash in the still A is properly deprived of spirit. It is for this reason that the introduction of continuously-working apparatus was necessary, in order to enlarge the scope of the distilling plant.

2.—Continuous or Uninterrupted Apparatus.

Apparatus of this type must be provided with efficient regulating appliances so that it is capable of proper automatic operation. In continuous distillation the process is briefly as follows: The fermented mash in an uninterrupted stream advances against a current of steam. The difference in the temperatures of these two currents is sufficient to effect the deprivation of the mash of all its alcohol, the spirit passing over to the steam. The steam thus impregnated with alcohol vapor passes into the rectifier and dephlegmator device, while the mash, in the form of spent wash, passes out of the apparatus. To reduce the heat consumption to a minimum, the mash itself is employed in the cooling apparatus and the dephlegmator.

A. Apparatus for the Production of Raw Spirit.

These apparatus are to be found in the majority of modern distilleries. The type most widely used is probably that designed by Savalle, in France, using the arrangement of the column devised by Champonnois, and that of Coffey in England. The general arrangement is shown in Fig. 66. This type of continuously-working, column apparatus is the one manufactured by many machine factories.

The apparatus comprises the following parts: *A*, the distilling column; *B*, the rectifier column; *C*, the concentrator; *D*, the condenser for the alcohol vapors; *E*, the outlet for the spent wash; and *G*, the outlet for the spirit. The mash is first raised by means of a pump and is forced through the tube *s* into the concentrator *C*, which is arranged to act as a pre-heater; the mash then passes in a pre-heated condition through the tube s_1 into the uppermost of the eleven chambers of the mash distilling column *A*. This column *A* consists of chambers provided with dropping tubes, which project above the bottom of each chamber and have their lower ends extend to below the level of the corresponding tube in the adjacent chamber, so that in each of these chambers a layer of mash of a certain height remains, while the direct passage of the vapor

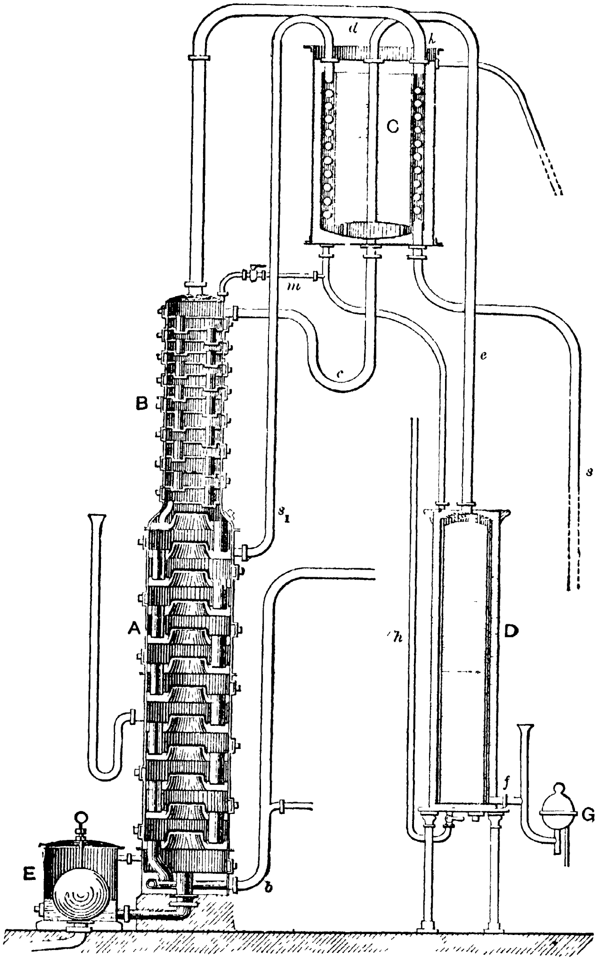

FIG. 66.—GENERAL TYPE OF COLUMN APPARATUS.

through these tubes is avoided as the tubes project into the mash. The mash passes in a constant stream through the tube s_1, and from chamber to chamber of the column *A* until it is completely deprived of spirit and passes through the automatic outlet device *E*. Steam is introduced into the lowest division of the distilling column through the pipe *b*, and hereby the last remnant of alcohol is distilled off from the mash, which has previously been freed from spirit to a large extent. The evolved vapors pass through a wide opening in each chamber to the one above; as this opening is provided with a flanged cap extending into the mash, the vapors must force their way through the mash of each chamber, bringing this to the point of ebullition and being, in turn, strengthened thereby. In this manner the steam flows against the current of the mash and gradually enriches itself with alcohol during its progress. Finally, the alcoholic vapors pass out from the uppermost chamber of the mash column *A*, into the rectifier column *B*, which, in the apparatus in question, comprises fifteen chambers placed one above the other, and provided with sieve-like, perforated bottoms and dropping tubes. The alcoholic vapor traverses the rectifier column *B* and enters the concentrator *C* through the pipe *d*. The concentrator consists of a comparatively large casing filled with water and enclosing a double-walled, annular vessel which in turn surrounds a copper worm. The fermented mash is pumped through the worm and is heated by the alcohol vapors in the annular vessel, while the vapors in turn are cooled by the cold mash. During this process a weakly alcoholic part is condensed and flows through the tube *c* into the uppermost chamber of the rectifier column *B*, while the uncondensed alcohol vapors pass into the condenser *D* through the tube *e*, and are here condensed and drawn off as strong spirit through the spirit outlet *G*.

The part condensed in the concentrator flows through the tube *c* into the uppermost chamber of the rectifier column *B*, in which the liquid is allowed to flow from chamber to chamber through the dropping tubes. During this operation it traverses perforated partitions through which the alcohol vapors constantly rise from the distilling column *A*. The vapors gradually bring the alcoholic fluid to ebullition, so that it returns to the distilling column *A* quite thoroughly deprived of spirit, and here it finally is completely deprived of its alcohol. The alcoholic vapors developed in the rectifier column constantly pass into the concentrator *C* where they undergo the necessary strengthening. The arrangement of the column apparatus therefore is based upon the repeated condensing of the alcoholic vapors by cooling and the revolatilization of the condensed liquid in a strengthened condition. Its action is, therefore, equivalent to a repeated distillation, accompanied by strengthening, condensation, revaporization, etc. It was through the introduction of the column distilling apparatus that the manufacture of spirit really became an effective industry.

It is sometimes customary to build the column distilling apparatus in two parts because of its great height, so that the rectifying column is located not upon the distilling column, but alongside of it. This arrangement also has the advantage that the so-called spindlings or low wine, with its constituents, does not pass into the wash, whereby the latter is recovered in a more concentrated condition. Wash of this character is at times desirable. The two-part apparatus, an example of which is illustrated in Fig. 67, are somewhat more expensive than the single apparatus, by reason of the greater quantity of material necessary in their construction. Furthermore, the operation of the former necessitates somewhat greater care and attention.

With the continuous distilling apparatus of the kind described above, it is possible, with single distillation, to

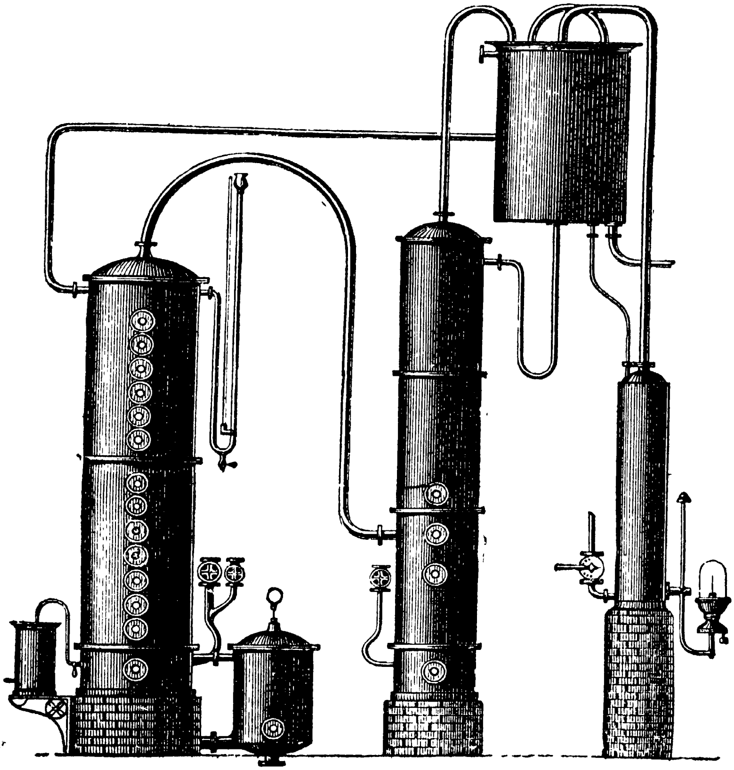

FIG. 67.—TWO-PART COLUMN DISTILLING APPARATUS.

obtain spirit of 80 to 87 per cent by volume. During recent years the technical utilization of alcohol on a large scale, has increased the requirements with regard to the efficiency of production in the apparatus, and has necessitated the manufacture of raw spirit of as high a grade as possible.

B. The Modern Dephlegmator.

The introduction of the dephlegmator marked a decided advance in the distilling industry. The dephlegmator really constitutes an improvement of that part of the apparatus which effects the strengthening of the alcohol vapor arising from the distilling column. This operation was carried out in the earlier constructions by a definite, regulated co-operation of the rectifier column and the concentrator, so that the alcoholic vapors escaping from the rectifier column were condensed in the concentrator and were returned in the form of low wine to the former where they were again volatilized. The vapor from the rectifier column was strengthened to a distillate rich in alcohol by means of the vapors rising from the distilling column, and the strengthened vapor then passed into the concentrator, where in a manner similar to the condensation of the low wine it was partly condensed against the cooling walls, the uncondensed vapor escaping into the condenser. The object of the dephlegmator is to effect the condensation of the alcohol vapors arising from the distilling column, as well as to accomplish the revolatilization of the condensed liquid present in the form of drops. The effect of the strengthening of the rising spirit vapor accomplished in this manner, is greater the more frequently the condensation and revaporation are carried out and the more thoroughly each individual part of the spirit enters into this process. It is for this reason that in the construction of the apparatus especial stress is laid upon the effecting of a very rapid and thorough exchange of heat between the alcoholic vapors and the cooling liquid, as well as upon the greatest possible diffusion of the condensed "phlegm," or water of distillation. With this apparatus it is possible to obtain products of considerably higher grade than that yielded by the former condensing appliances. The average strength of the alcohol produced by distilling apparatus having dephlegmators is 89 to 92 per cent by volume. This fact is extremely favorable to the wider use of spirit for technical purposes, for heating, lighting, and motive power. Furthermore, it decreases the useless ballast of water with which the alcohol is otherwise laden. Finally, by the elimination of a special rectifying column and the consequent decrease in the height of the apparatus, the latter is far simpler in construction and presents less difficulty of installation in the distillery building. The dephlegmator has been found efficient and successful in operation wherever introduced.

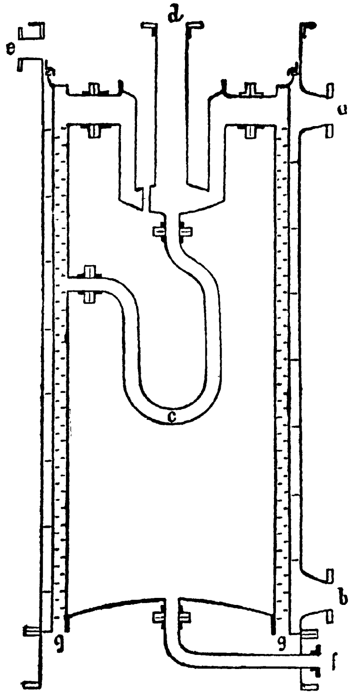

FIG. 68.—A MODERN FORM OF DEPHLEGMATOR.

In recent years a series of dephlegmators based upon the principle described above, has been designed and placed upon the market. The first of these, which was thoroughly tested in practice, was designed by J. Verchow, Germany. The same apparatus as constructed by

Schmidt & Son, Nauen, Mecklenburg, Germany, is illustrated in Fig. 68. This type of the device consists mainly of three casings located one within the other. The inner casing on its outer side, and the middle casing on both its inner and outer sides are provided with annular angle flanges riveted in position. The mash is pumped into the dephlegmator through the inlet *a*, and flows between the outer and the middle casing in a gradual spiral path formed by the flanges to the outlet *b*, from which it passes through a pipe to the mash column. The alcohol vapors arising from the mash column enter the dephlegmator at *g*, and are forced to flow back and forth by the flanges upon the outer side of the inner casing and the inner side of the middle casing, until they collect in a low wine chamber located at the upper portion of the dephlegmator, and from thence pass into the condenser through a tube *d*. The alcohol vapor, which is condensed, and the resulting low wine pass through the U-shaped tube *c* between the flanged casings, and trickle through these downward into the upper part of the mash column.

The inner casing is filled with cooling water, which also surrounds the low wine chamber completely. The mash is heated by contact with the warm outer wall of the middle casing, and at the same time cools off the alcohol vapors. The cooling water overflows through the openings *e*. After the completion of the operation, the dephlegmator is emptied by drawing off the water through the tube *f*. If the flow of the mash should be retarded by choking of the passages the right- and left-hand screw-joint, indicated at *g*, is loosened and the outer casing is slipped off. The two inner casings are rendered tight against the outer casings by means of a rubber ring at the upper end.

Slight differences only are found between the above described dephlegmator and those of W. Böckenhagen,

R. Dähne, and D. Ewald, all of Germany. The limited room which these apparatus require must be taken into consideration in judging the results obtained with them.

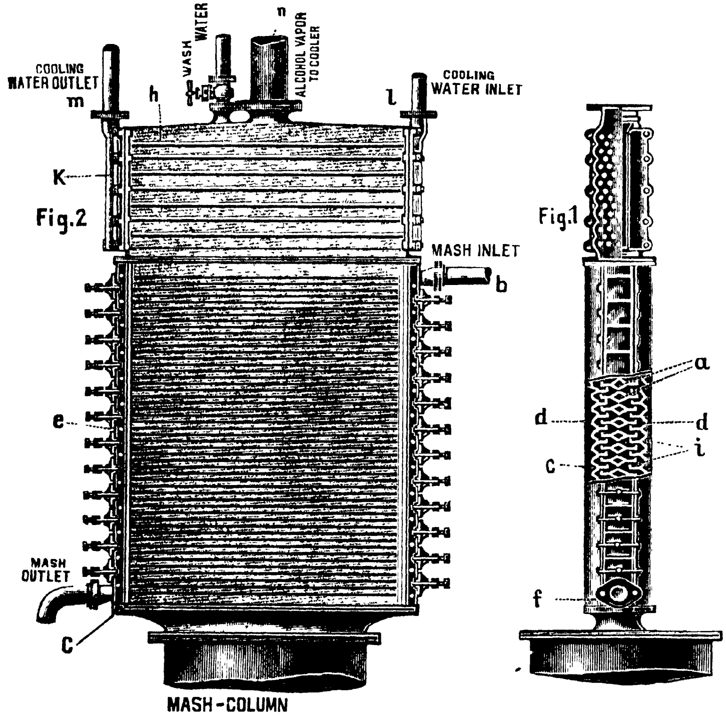

FIG. 69.—WAGENER TYPE OF DEPHLEGMATOR.

It should be noted that these systems too, have been found efficient in practice. The dephlegmator constructed by A. Wagener differs considerably from the form described above. It is illustrated in Fig. 69.

This apparatus is flat and rectangular in form, and has a length of about 3 feet, a width of about 4 inches, and a height of about 4½ feet. The mash enters at the point described as mash inlet in the illustration, and passes through the tubes *a*, visible in the cross section. The mash gradually passes downward along a sinuous path until it enters the distilling column, heated to about 167° F. The side walls of the dephlegmator are formed of corrugated sheet metal *d*. The mash tubes and the inward convolutions of the walls are provided with longitudinal metal strips *i* and *e*, soldered in place. The alcohol vapors arising from the distilling column are forced by the metal strips to pass sinuously upward between the cold mash tubes and the outer walls whereby the heat of evaporation of the vapors is largely given up in both directions. If the vapors are partly liquefied in consequence of this loss in heat, the liquid collects in drops upon the metal strips and in this form is again easily volatilized by the ascending vapors and converted into high grade vapor which, in turn, undergoes the same changes, so that the rising vapors are gradually strengthened. The strengthening progresses so far that after the dephlegmation and rectification has been completed in *K*, a second part of the apparatus mounted upon the true dephlegmator and filled with water tubes, the vapors can escape to the condenser with a strength of 89 to 91 per cent by volume. All the tubes in the apparatus are provided with locking caps, so that when necessary they can be removed easily to be cleaned with the cleansing brush or rod. The apparatus has already been introduced into a large number of plants, and has been operated successfully. On the whole, the introduction of the dephlegmator must be regarded as a practical and valuable advance in the development of the apparatus of the distilling industry.

The construction, arrangement and method of operation of the distilling apparatus were materially changed by Ilges, who designed complete and automatic regulating devices, and thereby effected a new form of distillation,

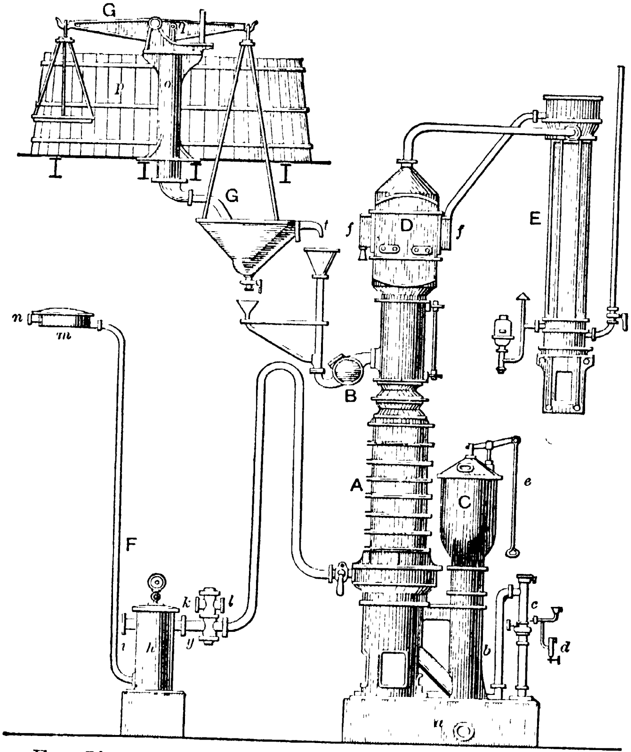

FIG. 70.—ILGES'S AUTOMATIC DISTILLING APPARATUS.

wherein the mash is located not in a distilling column provided with a plurality of chambers partially filled with mash and in contact with the air, but is introduced instead into a single continuous column. In Fig. 70 is shown the arrangement of Ilges's automatic apparatus. The mash flows from the mash container *p* through the outlet tube *G* into a funnel which is mounted on a scale; the outflowing current of the mash is accurately regulated by the movement of one of the scale beams. Through the outlet opening *t* and the inlet pipe *B*, the mash enters the distilling column *A*. The latter is completely filled with mash, and is provided with such arrangements only which demark a certain path for the mash.

The vapors evolved in the distilling column *A* subsequently pass into the dephlegmator and concentrator *D*, the lower part of which contains porcelain balls. Its upper part, on the other hand, is provided with water-filled cooling tubes, by means of which a partial condensation of the weaker vapors and a consequent strengthening are effected. The condensed liquid flows back into the mash column and here undergoes renewed distillation and strengthening, while the strengthened alcohol vapors are liquefied in the condenser *E*. The removal of the spent wash is accomplished by the outlet regulator *C*, designed very ingeniously by Ilges so that the introduction of the mash and the removal of the spent wash are exactly balanced. The most important part of Ilges's apparatus is, however, an automatic steam pressure appliance which regulates the entrance into the distilling column of exhaust steam or of live steam from the boilers, according to the necessity of the operation. Finally, the apparatus is provided with a water regulator, which insures uniform and constant pressure of the necessary cooling water.

C. Apparatus for the Production of High Percentage Spirit Direct from the Mash.

Ilges's distilling apparatus has in recent years been so perfected, that by means of it it is possible to obtain fine spirit directly from the mash without further rectification, the fusel oils being separated out in a single operation. The apparatus in its perfected form is characterized as an "Automatic Rectifier for the Production of Pure Spirit Direct from any Kind of Mash," and is said to yield three separate qualities of product: First, 90 per cent of the total alcohol contained in the mash in the form of high-grade spirit of 96 to 96.5 per cent by volume; secondly, the total fusel oil concentrated to 70 per cent; and lastly, all the foreshots at a strength of over 97 per cent by volume.

The character and the composition of the distilling liquid largely influence the method of operation and the yield of the apparatus which produce fine spirit directly from the mash. The efficiency of such apparatus is dependent to a greater or less extent upon the character of the mash, whether the latter be a concentrated mash rich in alcohol, an attenuated mash poor in spirit, or an air-yeast wort. In the last case the demands placed upon the rectifying apparatus are decidedly greater.

Apparatus which have been found efficient in practice in this regard are: The continuous distilling and rectifying apparatus based upon the system of Guillaume, the low pressure, mash distilling apparatus of F. Pampe, Germany, and the mash distilling and rectifying apparatus for continuous operation of Strauch, Germany, producing fine spirit directly from the mash. Apparatus of this character has recently been introduced into grain distilleries and air-yeast factories by Becker Bros., Germany.

V.—CLEANING THE DISTILLING APPARATUS.

Distilling apparatus can be cleansed by steaming or in the usual manner with hot water. A simpler method is as follows:

After long use, distilling apparatus occasionally acquires a crust having a thickness up to 3/4 inch, consisting of hardened mash, grease, sand, yeast cells, husks, etc. To remove this without taking the apparatus apart, the latter is filled with cold water. After a short interval the water is drawn off, all outlets are opened and a copper pan filled with equal parts of alcohol and kerosene is inserted from the side and set on one of the vapor pipe caps. The mixture is then lighted. In three or four minutes the chamber becomes dry and hot and the crust so loose that it can be easily removed. The process is repeated with each chamber, beginning at the lowest. With a gallon of the mixture the largest apparatus can be cleaned in four hours.

VI.—RECTIFICATION AND PURIFICATION OF ALCOHOL.

The chief purpose of the process of rectification lies in the removal of the volatile oils, embraced in practice under the general term of *fusel oil,* in order to obtain pure alcohol. In rectification it is, of course, of greatest importance to be able to ascertain, first of all, whether or not alcohol contains fusel oil. It is generally conceded that there are no reliable chemical means for the purpose of this determination, and in practice the senses of taste and smell are usually relied upon to detect the presence of the impurities. However, according to Vogel, if nitrate of silver be added to pure alcohol and the mixture be placed in strong sunlight the alcohol remains quite clear, while if it contains fusel oil, the liquid becomes tinged with red. Göbel has proposed the following method for testing alcohol with regard to its origin: 100 parts of the brandy or spirits to be examined, are taken, and to this 1 part of potassium hydrate together with a small quantity of water, is added. The mixture is evaporated after agitation to 15 parts; 15 parts of dilute sulphuric acid are then added, and the mixture is thoroughly shaken. The resulting odors are characteristic of the spirit examined. Thus, potato spirit evolves a peculiarly unpleasant odor, which causes headache and giddiness when inhaled, that of malt spirit resembles the odor of sour dough, and similarly rum, brandy, and other spirits each possess a characteristic and easily distinguishable smell.

As has already been mentioned, the larger or smaller quantities of contaminating constituents which accompany the pure ethyl alcohol in the raw spirit of distillation are designated collectively as *fusel oils*. The characterization is rather a loose one, for, chemically, amyl alcohol is the only fusel oil. The impurities in raw spirit comprise many other substances besides amyl alcohol, however, and these with their boiling points, as far as at present established, are given below:

Water	212° F.
Acetaldehyde	69.8° F.
Propyl alcohol	206.6° F.
Isopropyl alcohol	185° F.
Butyl alcohol	239° F.
Isobutyl alcohol	226.4° to 228.2° F.
Ethyl acetic ester	165.2° F.
Ethyl butyric ester	233.6° F
Acetal	219.2° F.
Isoamyl alcohol	248° F
Amyl alcohol	269.6° F
Furfurole	320° F

To separate the impurities from ethyl alcohol the raw spirit is subjected to fractional distillation. It will be remembered that it is impossible by a single distillation to effect the separation of two bodies even if they have different boiling points, since the bodies boiling at lower temperatures will always be mixed with compounds boiling at higher temperatures, and *vice versa*. Therefore, before a quantitative separation of two bodies is possible to a definite degree, repeated distillation must be carried out. In practice, the repeated distillation is effected by condensing the vapors in columns and concentrators provided in the rectifying apparatus. The ease or difficulty with which mingled bodies can be separated depends, first, upon the ease with which they are physically miscible, regardless of their respective boiling points, and, secondly, upon the proximity of their respective points of ebullition. Rectification of alcohol is merely fractional distillation frequently repeated. If the raw spirit contains few contaminating constituents the refining value will be higher, for the by-products can then be more readily and more completely separated out. In rectification four products are obtained: 1, *first running or foreshots,* a mixture of acetaldehyde and ethyl alcohol, which has a lower boiling point than ethyl alcohol, and is known by the refiner as *ether;* 2, *clean or rectified spirit,* which includes in the middle of the operation the highest product of rectification, while at first it is contaminated with some acetaldehyde and toward the end with alcohols having higher boiling points; 3, *feints,* a mixture of various alcohols, including a small quantity of ethyl alcohol and large quantities of alcohols having higher boiling points, particularly amyl alcohol; 4, *fusel oil,* which remains in the rectifying apparatus together with the major portion of the water.

VII.—RECTIFYING APPARATUS.

Where apparatus for the direct production of pure spirit is not available, or where spirit of particularly high grade is requisite, special apparatus must be employed for the purification of the raw spirit by separating out the by-products of unpleasant taste and smell, the fusel oils. For this purpose rectifying apparatus which is based on the principle of that first constructed by Savalle, in France, is generally used. Rectifying apparatus, of special construction and differing from Savalle's design, is also employed in many distilleries. This includes such devices as those constructed in Germany by Heckmann, Pampe, Becker Bros., and others. Savalle's rectifying apparatus is illustrated in Fig. 71.

The operation of this apparatus is not continuous, but is periodic. The large still *A* is filled with the spirit to

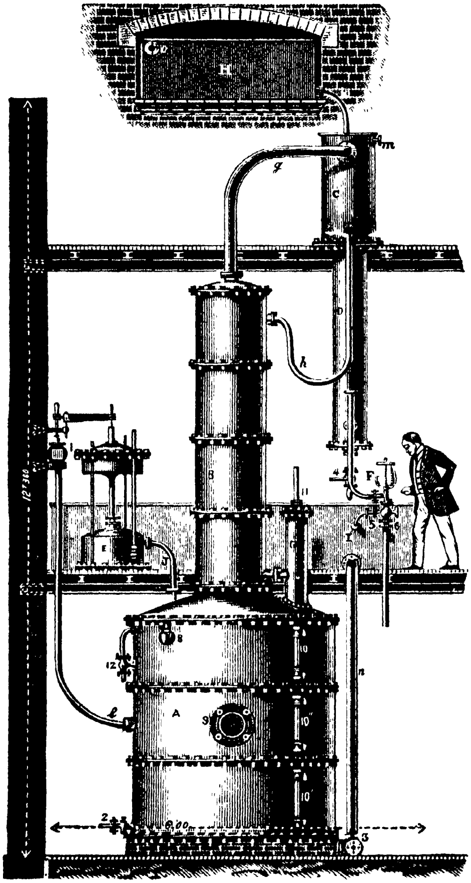

FIG. 71.—SAVALLE'S RECTIFYING APPARATUS.

be purified, which has been diluted to 40 to 50 per cent in strength. The spirit is slowly volatilized by means of a steam coil located in the still, which is divided into two parts by means of a partition. The upper, smaller part serves as a low wine chamber as in the Pistorius apparatus. *B* is the rectifying column; it comprises the known perforated partitions placed one above the other and connected by dropping tubes. The column corresponds in arrangement to that of the column-distilling apparatus illustrated on page 305. *C* is the concentrator from which the condensed part of the vapors flows back into the upper chamber of the rectifier column *B* through the pipe *h;* *D* is the condenser, and *F* the spirit outlet.

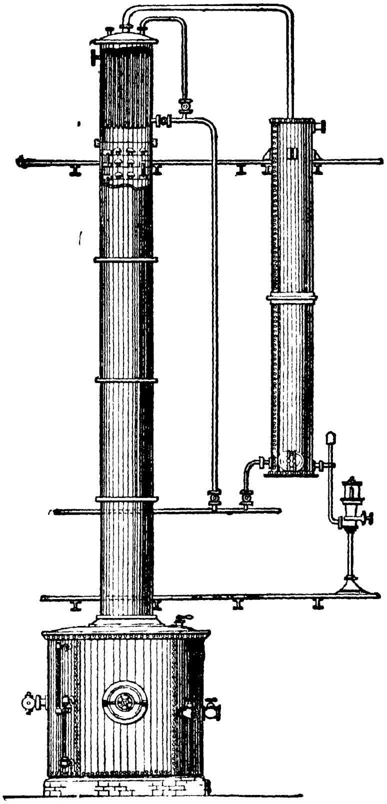

Fig. 72.—Heckmann's Rectifying Apparatus.

In Fig. 72 is illustrated Heckmann's bell rectifying apparatus, which includes a large wrought iron still provided with two steam coils, a copper column placed upon the still and in turn carrying a concentrator. One of the steam coils in the still is used for heating purposes during the actual rectification, while the other, which is perforated with fine holes, is used to expel the last remnants of spirit. The column contains 36 to 42 horizontal partitions uniformly spaced. Each of these is provided with an overflow pipe, a rim, and a number of bell-shaped members. The number of the latter depends upon the capacity of the apparatus. The operation is the usual one, the condensed liquid returning to the still through the overflow pipes, while the rising vapors are forced by the bells to pass in a uniformly thin layer through the boiling fluid. The concentrator is so arranged that the vapors pass through it upward instead of downward. This operation, it is claimed, effects more thorough purification and concentration. For the purpose of preheating, the concentrator pipes may project into the head of the column.

In Pampe's low pressure rectifying apparatus, illustrated in Fig. 73, the cylindrical still is open from top to bottom, and contains a coil of very large heating surface. The apparatus is provided with a device which prevents portions of the fluid from being carried into the column, even with the most vigorous ebullition, and this assists in subjecting the low wine from the column to a surface rectification before entering the still. The construction of the rectifying column is such that the operating pressure is slight, with an intense mixture of vapor and fluid. The effect of this arrangement is a decrease in the consumption of heat, and an improvement in the distillate. The dephlegmator operates upon the principle of counter-current between steam and separated low wine, as well as upon counter-current between steam and cooling water. By means of an intermediate appliance the steam entering the condenser is of the highest quality, being previously freed from particles of fluid. The apparatus is provided with

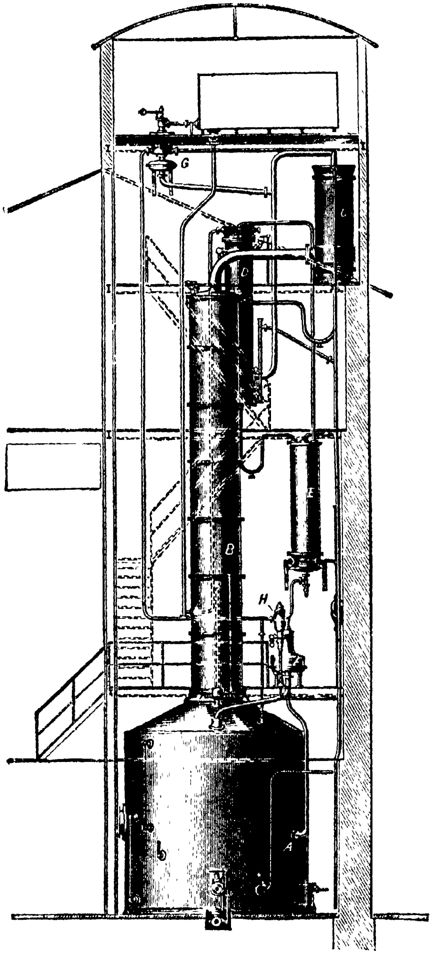

FIG. 73.—PAMPE'S LOW-PRESSURE RECTIFYING APPARATUS.

regulating devices which have been found very effective in practice; among these are the steam regulator, the cooling water inlet regulator, and the discharge regulator. The distillate is discharged from the condenser in perfect quiet. This is assisted by an open pipe in the concentrator, which is entirely separated from the discharge of the rectified product.

VIII.—SUBSTANCES USED FOR THE PURIFICATION OF ALCOHOL DURING RECTIFICATION.

The rectification of the alcohol effected in distilleries and spirit refineries by means of the apparatus described above, can be assisted and completed by other means. Among these is, first of all, the treatment with carbon, or rather, filtration of the raw spirit through carbon. The purifying action of carbon, which is usually employed in the form of charcoal from bass or beechwood, or of vegetable charcoal, such as charred peat or bone black, improves the taste and the smell of the spirit which is treated therewith. The charcoal should be as light and porous as possible. It is still an open question whether the effect of the charcoal is, as Maercker declares, of a purely physical, absorptive nature, or whether it is due to the chemical action of the carbon, as claimed by Glasenapps. Formerly, the charcoal, when used for purposes of alcohol purification, was added to the spirit in a finely divided condition, and the latter allowed to stand thus for twenty-four hours. Then, the spirit was drawn off from above the charcoal, which had settled upon the bottom of the vat. In another method the spirit diluted to from 40 to 50 per cent was passed through a filter apparatus. This was constructed by introducing a filtering mass such as a layer of gravel, into the wooden filtering vat and filling the latter with charcoal to a depth of about 4½ or 5 feet above the gravel. This incomplete method, which is to-day still employed in many small plants, is unsuited for operation on a greater scale; in large distilleries it is now replaced by systematic filtration through a plurality of filters combined into a battery. These filters are filled with charcoal broken up to the size of peas or hazel nuts. After using the charcoal, the filters are steamed for the purpose of recovering the spirit retained, and the charcoal is heated to redness in order to regenerate it, or, according to Pampe, it is treated with superheated steam.

The use of chemical means for the purification of raw spirit has so far been attended with little success. The chemical substances proposed vary widely and include soap, oil, and fatty substances, soda, lime, permanganate of potash, sulphuric and nitric acids. All recommended methods of this character should be investigated carefully, especially as many of them merely produce an apparent improvement by evolving substances which serve as disguising means, and become ineffective after standing for a longer period, or through the addition of water. When spirit is stored in the wood the disagreeable taste due to recent distillation often disappears. This action is due to absorption by the wood, and to the slight oxidation and etherification of the higher alcohols. Certain alcoholic extracts of fruits, such as prune juice, peach juice, raisin extract and Saint John's bread extract, are used to hide the rough and unpleasant taste of newly distilled spirit.

The chemical methods of purifying alcohol must not be confounded with the application of carbonic or caustic alkalies for purposes of neutralization prior to rectification, in order to eliminate decomposition as far as possible. Attempts to deprive spirit of fusel oil by electrolytic means have, up to the present, been attended with little success. Among special methods for purifying spirit, should be mentioned the "Killing-Oppenheim" process for improving raw spirit, especially for freeing foreshots from aldehyde. This depends upon the treatment of raw spirit, diluted to 40 per cent, with a weak current of air at 122° to 140° F., whereby the aldehyde is evaporated after ten to twelve hours.

IX.—ALCOHOLOMETRY, THE INVESTIGATION OF THE SPIRIT.

Alcoholometry, the investigation of the alcohol with regard to its content of spirit, is carried out by testing the liquid with an alcoholometer. In the pure state alcohol at the standard temperature of 15½° C., or 59.9° F., for which the alcoholometer is designed, possesses a specific gravity of 0.7946; the lower the content of alcohol in a mixture of alcohol and water, the higher is the specific gravity of the mixture, that is, the nearer does the specific gravity approach the figure 1, which represents the specific gravity of water. A definite content of alcohol in a mixture of alcohol and water corresponds to each specific gravity, so that it is possible to ascertain through the determination of the specific gravity the exact degree of strength of diluted, but otherwise pure alcohol. The instrument for this purpose, the alcoholometer, resembles the saccharometer, with the exception that it registers higher degrees of strength the deeper it sinks into the liquid investigated, while the saccharometer registers a higher sugar content the less deeply it is submerged in the liquid. Naturally, this is due to the fact that a higher specific gravity in the second case corresponds to the greater sugar content, while a lower specific gravity results from a higher content of alcohol in the first.

The strength of the alcohol is expressed in percentage by volume and by weight. Volume and weight percentages do not correspond, because in mixing water and alcohol a contraction occurs. For instance, if 50 gallons of alcohol are mixed with 50 gallons of water, instead of obtaining 100 gallons of 50 per cent alcohol, only 96.4 gallons of diluted alcohol, in which there are 50 gallons of absolute alcohol, are obtained, because of the contraction of 3.6 gallons, which results from the mixing. Consequently, a mixture of this character does not contain 50, but 51.8 per cent by volume of alcohol. By weight the matter is different. Fifty gallons of absolute alcohol weigh about 349.5 pounds, and 50 gallons of water weigh 440 pounds, the total weight being 789.5 pounds. The mixture contains 349 pounds of absolute alcohol, which corresponds to 44.3 per cent by weight. The first of the accompanying tables is a *résumé* of the specific weights of mixtures of alcohol and water, as well as of the corresponding percentages by volume and by weight. The second contains the percentages by volume and by weight, according to Brix, for the determination of the true strengths of alcohol at 60° C. or 140° F., from the apparent strengths as indicated by the alcoholometer at different degrees of temperature. The apparent strength of alcohol is the reading of the alcoholometer at a temperature deviating from the normal temperature of the instrument, while the true strength is the corresponding one at the normal or standard temperature. The table is used as follows: The line at the top of the table represents the actual readings, and the true strength is ascertained from the column under the actual reading, corresponding to the actual temperature given in the first two vertical columns.

NO. 1. SPECIFIC GRAVITY OF MIXTURES OF ALCOHOL AND WATER, AND THE CORRESPONDING PER CENT. BY VOLUME AND BY WEIGHT OF ALCOHOL AT 60° F.

Per cent.	Per cent. by Volume.	Per cent. by Weight.	Per cent.	Per cent. by Volume.	Per cent. by Weight.	Per cent.	Per cent. by Volume.	Per cent. by Weight.
	Corresponding Specific Gravity.			Corresponding Specific Gravity.			Corresponding Specific Gravity.	
1	0.9985	0.9981	35	0.9592	0.9490	68	0.8949	0.8772
2	9970	9963	36	9579	9472	69	8925	8748
3	9956	9944	37	9565	9453	70	8900	8724
4	9942	9928	38	9550	9433	71	8875	8700
5	9928	9912	39	9535	9413	72	8850	8676
6	9915	9896	40	9519	9394	73	8825	8652
7	9902	9880	41	9503	9374	74	8799	8629
8	9890	9866	42	9487	9353	75	8773	8605
9	9878	9852	43	9470	9332	76	8747	8581
10	9866	9839	44	9452	9311	77	8720	8557
11	9854	9826	45	9435	9291	78	8693	8533
12	9843	9813	46	9417	9269	79	8666	8509
13	9832	9800	47	9399	9248	80	8639	8484
14	9821	9788	48	9381	9227	81	8611	8459
15	9811	9775	49	9362	9204	82	8583	8435
16	9800	9763	50	9343	9183	83	8555	8409
17	9790	9751	51	9323	9160	84	8526	8385
18	9780	9739	52	9303	9138	85	8496	8359
19	9770	9727	53	9283	9116	86	8466	8333
20	9760	9714	54	9263	9094	87	8436	8307
21	9750	9702	55	9242	9072	88	8405	8282
22	9740	9690	56	9221	9049	89	8373	8256
23	9729	9677	57	9200	9027	90	8339	8229
24	9719	9664	58	9178	9004	91	8306	8203
25	9709	9651	59	9156	8981	92	8272	8176
26	9698	9637	60	9134	8958	93	8237	8149
27	9688	9622	61	9112	8935	94	8201	8122
28	9677	9607	62	9090	8911	95	8164	8094
29	9666	9592	63	9067	8888	96	8125	8065
30	9655	9577	64	9044	8865	97	8084	8036
31	9643	9560	65	9021	8842	98	8041	8006
32	9631	9544	66	8997	8818	99	7995	7976
33	9618	9526	67	8973	8795	100	7946	7946
34	9605	9508						

NO. 2. TABLE FOR THE DETERMINATION OF THE TRUE STRENGTHS OF ALCOHOL AT 140° F. FROM THE APPARENT STRENGTHS INDICATED BY THE ALCOHOLOMETER AT DIFFERENT DEGREES OF TEMPERATURE.

Degrees F.	Degrees R.	71	72	73	71	75	76	77	78	79	80
		Strengths of Alcohol for Above Apparent Strengths. (PER CENT. BY VOLUME.)									
+34.25	+1	75.4	76.4	77.4	78.4	79.3	80.3	81.2	82.2	83.1	84.1
36.5	2	75.1	76.0	77.0	78.0	79.0	80.0	80.9	81.9	82.8	83.8
38.75	3	74.7	75.7	76.7	77.6	78.6	79.6	80.6	81.5	82.5	83.4
41.0	4	74.3	75.3	76.3	77.3	78.3	79.2	80.2	81.2	82.1	83.1
43.25	5	73.9	74.9	75.9	76.9	77.9	78.8	79.8	80.8	81.8	82.7
45.5	6	73.5	74.5	75.5	76.5	77.5	78.4	79.4	80.4	81.4	82.4
47.75	7	73.1	74.1	75.1	76.1	77.1	78.0	79.0	80.0	81.0	82.0
50.0	8	72.7	73.7	74.7	75.7	76.7	77.6	78.6	79.6	80.6	81.6
52.25	9	72.3	73.3	74.3	75.3	76.3	77.3	78.3	79.2	80.2	81.2
54.5	10	72.0	72.9	73.9	74.9	75.9	76.9	77.9	78.9	79.9	80.9
56.75	11	71.6	72.6	73.5	74.5	75.5	76.5	77.5	78.5	79.5	80.5
59.0	12	71.2	72.2	73.2	74.2	75.2	76.2	77.2	78.2	79.2	80.2
61.25	13	70.8	71.8	72.8	73.8	74.8	75.8	76.8	77.8	78.8	79.8
63.5	14	70.4	71.4	72.4	73.4	74.4	75.4	76.4	77.4	78.4	79.4
65.75	15	70.1	71.1	72.1	73.1	74.1	75.1	76.1	77.1	78.1	79.1
68.0	16	69.7	70.7	71.7	72.7	73.7	74.7	75.7	76.7	77.7	78.7
70.25	17	69.2	70.3	71.3	72.3	73.3	74.3	75.3	76.3	77.3	78.3
72.5	18	68.8	69.8	70.8	71.8	72.8	73.8	74.8	75.9	76.9	77.9
74.75	19	68.4	69.4	70.4	71.4	72.4	73.4	74.4	75.5	76.5	77.5
77.0	20	68.0	69.0	70.0	71.0	72.1	73.1	74.1	75.1	76.1	77.2
79.25	21	67.6	68.6	69.6	70.6	71.7	72.7	73.7	74.7	75.8	76.8
81.5	22	67.1	68.2	69.2	70.2	71.2	72.3	73.3	74.3	75.3	76.4
83.75	23	66.7	67.7	68.7	69.7	70.8	71.8	72.8	73.9	74.9	76.0
86.0	24	66.2	67.2	68.3	69.3	70.3	71.4	72.4	73.4	74.5	75.5
88.25	25	65.8	66.8	67.9	68.9	69.9	71.0	72.0	73.0	74.1	75.1

NO. 2. TABLE FOR THE DETERMINATION OF THE TRUE STRENGTHS OF ALCOHOL AT 140° F. FROM THE APPARENT STRENGTHS INDICATED BY THE ALCOHOLOMETER AT DIFFERENT DEGREES OF TEMPERATURE (Continued).

Degrees F.	Degrees C.	71	72	73	74	75	76	77	78	79	80
		Strengths of Alcohol for Above Apparent Strengths. (PER CENT. BY WEIGHT.)									
+33.8	+1	75.8	76.8	77.8	78.8	79.8	80.8	81.8	82.8	83.8	84.6
35.6	2	75.4	76.4	77.4	78.4	79.4	80.4	81.4	82.4	83.4	84.4
37.4	3	75.2	76.0	77.2	78.0	79.0	80.0	81.0	82.0	83.0	84.0
39.2	4	74.8	75.8	76.8	77.8	78.8	79.8	80.8	81.8	82.8	83.6
41.0	5	74.4	75.4	76.4	77.4	78.4	79.4	80.4	81.4	82.4	83.4
42.8	6	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0	82.0	83.0
44.6	7	73.8	74.8	75.8	76.8	77.8	78.8	79.8	80.8	81.8	82.8
46.4	8	73.4	74.4	75.4	76.4	77.4	78.4	79.4	80.4	81.4	82.4
48.2	9	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0	82.0
50.0	10	72.8	73.8	74.8	75.8	76.8	77.8	78.8	79.8	80.8	81.8
51.8	11	72.4	73.4	74.4	75.4	76.4	77.4	78.4	79.4	80.4	81.4
53.6	12	72.0	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0
55.4	13	71.6	72.6	73.6	74.6	75.6	76.6	77.6	78.6	79.6	80.6
57.2	14	71.4	72.4	73.4	74.4	75.4	76.4	77.4	78.4	79.4	80.4
59.0	15	71.0	72.0	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0
60.8	16	70.6	71.6	72.6	73.6	74.6	75.6	76.6	77.6	78.6	79.6
62.6	17	70.4	71.4	72.4	73.4	74.4	75.4	76.4	77.4	78.4	79.4
64.4	18	70.0	71.0	72.0	73.0	74.0	75.0	76.0	77.0	78.0	79.0
66.2	19	69.6	70.6	71.6	72.6	73.6	74.6	75.6	76.6	77.6	78.6
68.0	20	69.2	70.2	71.2	72.2	73.2	74.2	75.2	76.2	77.2	78.2
69.8	21	69.0	70.0	71.0	72.0	73.0	74.0	75.0	76.0	77.0	78.0
71.6	22	68.6	69.6	70.6	71.6	72.6	73.6	74.6	75.6	76.6	77.6
73.4	23	68.2	69.2	70.2	71.2	72.2	73.2	74.2	75.2	76.2	77.2
75.2	24	67.8	68.8	69.8	70.8	71.8	72.8	73.8	74.8	75.8	76.8
77.0	25	67.4	68.4	69.4	70.4	71.4	72.4	73.4	74.6	75.6	76.6

NO. 2. TABLE FOR THE DETERMINATION OF THE TRUE STRENGTHS OF ALCOHOL AT 140° F. FROM THE APPARENT STRENGTHS INDICATED BY THE ALCOHOLOMETER AT DIFFERENT DEGREES OF TEMPERATURE (Continued).

Degrees F.	Degrees R.	81	82	83	84	85	86	87	88	89	90
		Strengths of Alcohol for Above Apparent Strengths. (PER CENT. BY VOLUME)									
+34.25	+1	85.0	86.0	86.9	87.8	88.8	89.7	90.7	91.6	92.5	93.4
36.5	2	84.7	85.7	86.6	87.5	88.5	89.4	90.4	91.3	92.2	93.1
38.75	3	84.4	85.4	86.3	87.2	88.2	89.1	90.1	91.0	91.9	92.8
41.0	4	84.1	85.0	86.0	86.9	87.9	88.8	89.8	90.7	91.6	92.6
43.25	5	83.7	84.7	85.6	86.6	87.5	88.5	89.4	90.4	91.3	92.3
45.5	6	83.3	84.3	85.3	86.2	87.2	88.1	89.1	90.0	91.0	92.0
47.75	7	82.9	83.9	84.9	85.9	86.8	87.8	88.8	89.7	90.7	91.7
50.0	8	82.5	83.5	84.5	85.5	86.5	87.5	88.4	89.4	90.4	91.4
52.25	9	82.2	83.2	84.2	85.1	86.1	87.1	88.1	89.1	90.1	91.1
54.5	10	81.8	82.8	83.8	84.8	85.8	86.8	87.8	88.8	89.8	90.8
56.75	11	81.5	82.5	83.5	84.5	85.5	86.5	87.5	88.5	89.5	90.5
59.0	12	81.2	82.2	83.1	84.1	85.1	86.1	87.1	88.1	89.1	90.1
61.25	13	80.8	81.8	82.8	83.8	84.8	85.8	86.8	87.8	88.8	89.8
63.5	14	80.4	81.5	82.5	83.5	84.5	85.5	86.5	87.5	88.5	89.5
65.75	15	80.1	81.1	82.1	83.1	84.2	85.2	86.2	87.2	88.2	89.2
68.0	16	79.7	80.7	81.7	82.7	83.8	84.8	85.8	86.8	87.9	88.9
70.25	17	79.3	80.3	81.3	82.4	83.4	84.4	85.5	86.5	87.5	88.5
72.5	18	78.9	79.9	81.0	82.0	83.0	84.1	85.1	86.1	87.2	88.2
74.75	19	78.6	79.6	80.6	81.7	82.7	83.7	84.7	85.8	86.8	87.9
77.0	20	78.2	79.2	80.3	81.3	82.3	83.4	84.4	85.4	86.5	87.6
79.25	21	77.8	78.9	79.9	81.0	82.0	83.0	84.1	85.1	86.2	87.2
81.5	22	77.4	78.5	79.5	80.6	81.6	82.7	83.7	84.7	85.8	86.9
83.75	23	77.0	78.0	79.1	80.1	81.2	82.2	83.3	84.4	85.4	86.5
86.0	24	76.6	77.6	78.7	79.7	80.8	81.8	82.9	83.9	85.0	86.1
88.25	25	76.2	77.2	78.3	79.3	80.4	81.5	82.5	83.6	84.7	85.8

NO. 2. TABLE FOR THE DETERMINATION OF THE TRUE STRENGTHS OF ALCOHOL AT 140° F. FROM THE APPARENT STRENGTHS INDICATED BY THE ALCOHOLOMETER AT DIFFERENT DEGREES OF TEMPERATURE (Continued).

Degrees F.	Degrees C.	81	82	83	84	85	86	87	88	89	90
		Strengths of Alcohol for Above Apparent Strengths (Per Cent. by Weight.)									
+33.8	+1	85.6	86.6	87.6	88.6	89.6	90.4	91.4	92.4	93.2	94.2
35.6	2	85.4	86.4	87.2	88.2	89.2	90.2	91.2	92.0	93.0	94.0
37.4	3	85.0	86.0	87.0	88.0	88.8	89.8	90.8	91.8	92.8	93.6
39.2	4	84.6	85.6	86.6	87.6	88.6	89.6	90.6	91.4	92.4	93.4
41.0	5	84.4	85.4	86.4	87.2	88.2	89.2	90.2	91.2	92.2	93.0
42.8	6	84.0	85.0	86.0	87.0	88.0	89.0	89.8	90.8	91.8	92.8
44.6	7	83.6	84.6	85.6	86.6	87.6	88.6	89.6	90.6	91.6	92.4
46.4	8	83.4	84.4	85.4	86.4	87.4	88.2	89.2	90.2	91.2	92.2
48.2	9	83.0	84.0	85.0	86.0	87.0	88.0	89.0	90.0	91.0	91.8
50.0	10	82.8	83.8	84.6	85.6	86.6	87.6	88.6	89.6	90.6	91.6
51.8	11	82.4	83.4	84.4	85.4	86.4	87.4	88.4	89.4	90.2	91.2
53.6	12	82.0	83.0	84.0	85.0	86.0	87.0	88.0	89.0	90.0	91.0
55.4	13	81.6	82.6	83.6	84.6	85.6	86.6	87.6	88.6	89.6	90.6
57.2	14	81.4	82.4	83.4	84.4	85.4	86.4	87.4	88.4	89.4	90.4
59.0	15	81.0	82.0	83.0	84.0	85.0	86.0	87.0	88.0	89.0	90.0
60.8	16	80.6	81.6	82.6	83.6	84.6	85.6	86.6	87.6	88.6	89.6
62.6	17	80.4	81.4	82.4	83.4	84.4	85.4	86.4	87.4	88.4	89.4
64.4	18	80.0	81.0	82.0	83.0	84.0	85.0	86.0	87.0	88.0	89.0
66.2	19	79.6	80.6	81.6	82.6	83.6	84.6	85.6	86.6	87.8	88.8
68.0	20	79.2	80.2	81.2	82.4	83.4	84.4	85.4	86.4	87.4	88.4
69.8	21	79.0	80.0	81.0	82.0	83.0	84.0	85.0	86.0	87.0	88.0
71.6	22	78.6	79.6	80.6	81.6	82.6	83.6	84.6	85.6	86.8	87.8
73.4	23	78.2	79.2	80.2	81.2	82.2	83.4	84.4	85.4	86.4	87.4
75.2	24	77.8	78.8	79.8	81.0	82.0	83.0	84.0	85.0	86.0	87.0
77.0	25	77.6	78.6	79.6	80.6	81.6	82.6	83.6	84.6	85.8	86.8

NO. 2. TABLE FOR THE DETERMINATION OF THE TRUE STRENGTHS OF ALCOHOL AT 140° F. FROM THE APPARENT STRENGTHS INDICATED BY THE ALCOHOLOMETER AT DIFFERENT DEGREES OF TEMPERATURE (Continued).

Degrees F.	Degrees R.	91	92	93	94	95	96	97	98	99	100
		Strengths of Alcohol for Above Apparent Strengths. (PER CENT. BY VOLUME.)									
+34.25	+1	94.3	95.2	96.1	97.0	97.9	98.7	99.6			
36.5	2	94.1	95.0	95.9	96.8	97.6	98.5	99.4			
38.75	3	93.8	94.7	95.6	96.5	97.4	98.3	99.2			
41.0	4	93.5	94.4	95.4	96.3	97.2	98.1	99.0	99.9		
43.25	5	93.2	94.2	95.1	96.0	96.9	97.8	98.8	99.7		
45.5	6	92.9	93.9	94.8	95.8	96.7	97.6	98.5	99.5		
47.75	7	92.6	93.6	94.6	95.5	96.4	97.4	98.3	99.2		
50.00	8	92.3	93.3	94.3	95.3	96.2	97.1	98.1	99.0	99.9	
52.25	9	92.1	93.0	94.0	95.0	95.9	96.9	97.8	98.8	99.7	
54.5	10	91.7	92.7	93.7	94.7	95.7	96.6	97.6	98.6	99.5	
56.75	11	91.4	92.4	93.4	94.4	95.4	96.4	97.4	98.3	99.3	
59.0	12	91.1	92.1	93.1	94.1	95.1	96.1	97.1	98.1	99.1	
61.25	13	90.8	91.8	92.8	93.8	94.8	95.8	96.9	97.9	98.9	99.9
63.5	14	90.5	91.5	92.5	93.5	94.5	95.5	96.6	97.6	98.7	99.7
65.75	15	90.2	91.2	92.2	93.2	94.2	95.2	96.3	97.4	98.4	99.5
68.0	16	89.9	90.9	91.9	92.9	93.9	94.9	96.0	97.1	98.2	99.3
70.25	17	89.6	90.6	91.6	92.6	93.6	94.7	95.7	96.8	97.9	99.0
72.5	18	89.3	90.3	91.3	92.3	93.4	94.4	95.4	96.6	97.7	98.8
74.75	19	89.0	90.0	91.0	92.1	93.1	94.1	95.1	96.3	97.4	98.6
77.0	20	88.6	89.7	90.7	91.8	92.8	93.9	94.9	96.0	97.2	98.3
79.25	21	88.3	89.4	90.4	91.5	92.5	93.6	94.7	95.8	96.9	98.0
81.5	22	88.0	89.0	90.1	91.2	92.2	93.3	94.4	95.5	96.7	97.8
83.75	23	87.6	88.7	89.8	90.8	91.9	93.0	94.1	95.2	96.4	97.6
86.0	24	87.2	88.3	89.3	90.4	91.5	92.7	93.8	94.9	96.1	97.3
88.25	25	86.9	87.9	89.0	90.1	91.3	92.4	93.5	94.6	95.8	97.0

NO. 2. TABLE FOR THE DETERMINATION OF THE TRUE STRENGTHS OF ALCOHOL AT 140° F. FROM THE APPARENT STRENGTHS INDICATED BY THE ALCOHOLOMETER AT DIFFERENT DEGREES OF TEMPERATURE. (Concluded)

Degrees F.	Degrees C.	91	92	93	94	95	96	97	98	99	100
		Strengths of Alcohol for Above Apparent Strengths. (PER CENT. BY WEIGHT.)									
+33.8	+1	95.2	96.0	97.0	98.0	98.8	99.8				
35.6	2	94.8	95.8	96.8	97.6	98.6	99.6				
37.4	3	94.6	95.6	96.4	97.4	98.4	99.2				
39.2	4	94.2	95.2	96.2	97.2	98.0	99.0	100.0			
41.0	5	94.0	95.0	96.0	96.8	97.8	98.8	99.6			
42.8	6	93.8	94.6	95.6	96.6	97.6	98.4	99.4			
44.6	7	93.4	94.4	95.4	96.4	97.2	98.2	99.2			
46.4	8	93.2	94.0	95.0	96.0	97.0	98.0	98.8	99.8		
48.2	9	92.8	93.8	94.8	95.8	96.8	97.6	98.6	99.6		
50.0	10	92.6	93.6	94.4	95.4	96.4	97.4	98.4	99.4		
51.8	11	92.2	93.2	94.2	95.2	96.2	97.2	98.0	99.0		
53.6	12	92.0	93.0	94.0	94.8	95.8	96.8	97.8	98.8	99.8	
55.4	13	91.6	92.6	93.6	94.6	95.6	96.6	97.6	98.6	99.6	
57.2	14	91.4	92.4	93.4	94.2	95.2	96.2	97.2	98.2	99.2	
59.0	15	91.0	92.0	93.0	94.0	95.0	96.0	97.0	98.0	99.0	100.0
60.8	16	90.6	91.6	92.8	93.8	94.8	95.8	96.8	97.8	98.8	99.8
62.6	17	90.4	91.4	92.4	93.4	94.4	95.4	96.4	97.4	98.4	99.4
64.4	18	90.0	91.0	92.0	93.2	94.2	95.2	96.2	97.2	98.2	99.2
66.2	19	89.8	90.8	91.8	92.8	93.8	94.8	95.8	96.8	98.0	99.0
68.0	20	89.4	90.4	91.4	92.4	93.6	94.6	95.6	96.6	97.6	98.6
69.8	21	89.0	90.2	91.2	92.2	93.2	94.2	95.2	96.4	97.4	98.4
71.6	22	88.8	89.8	90.8	91.8	93.0	94.0	95.0	96.0	97.0	98.2
73.4	23	88.4	89.4	90.6	91.6	92.6	93.6	94.8	95.8	96.8	97.8
75.2	24	88.2	89.2	90.2	91.2	92.2	93.4	94.4	95.4	96.4	97.6
77.0	25	87.8	88.8	89.8	91.0	92.0	93.0	94.0	95.2	96.2	97.2

PART XII.

THE ARRANGEMENT OF THE DISTILLERY.

THE architectural arrangement of the distillery must in every detail take into consideration the existing local conditions, and due attention must be given all these conditions in the installation of the plant. In choosing the location of the distillery, consideration must be given the other farm buildings, especially the cattle stables, as well as the facilities for bringing the raw material to the plant and for removing the products. Furthermore, the conditions governing the water supply, especially the possibility of obtaining sufficient quantities of pure water, and the removal of the refuse water arising during the operations are of importance in governing the choice of the location. Sometimes, the simultaneous installation or the existence of other features, such as the dairy, thrashing machine, grist mill, or electric power plant, must be taken into account. Frequently, it is necessary to supply the living house and the farm buildings with water from the distillery. For the plant itself the following points should be noted:

The malt cellar must not be too small, as in the preparation of long malt it is necessary to allow for a germinating period of twenty days. For each thousand gallons of mashing capacity the malting floor should have an area of at least 96 square yards. A distillery designed for a mashing capacity of three times 750 gallons, therefore, must be provided with a malting floor of at least 210, though preferably 240 square yards. The malting floor should be built in the cellar, 4½ to 6 feet below the surface of the earth, and the same cellar floor should preferably also contain the spirit vaults. In general, these must be of such size that a spirit collecting vessel of a capacity equal to that of a railroad car lading can be erected therein, while 500 gallons are necessary as a reserve.

For setting up the decimal scale, and for the uses of the Revenue Department an area of about 35 square yards should further be provided in a plant of the size mentioned above. The fermenting room should preferably not be located below the surface of the earth, as with the present facilities for artificial heat regulation the question of a uniform temperature is no longer so difficult a one. In winter the fermenting room can be warmed, if necessary, by means of heating apparatus. Furthermore, movable vat cooling devices, in which either cold or warm water can be used in the cooling coils, provide convenient means for obtaining the desired temperature in the fermenting vats. Besides the fermenting room, the first floor should contain the yeast chamber, the engine room, the vestibule with the staircase, and if possible, a room for the revenue officials, which can be utilized at the same time as a laboratory. The fermenting room requires a floor space of 12.5 × 7.5 = 93.7 square yards for setting up ten vats each of 750 gallons capacity, allowing sufficient room about each vat to insure accessibility. The yeast chamber is large enough if it possesses a floor space of 6 × 3.3 = 19.8 square yards. In the yeast chamber there should be provided a special heating chamber to receive the yeast vessels during souring; the latter should be mounted upon rollers so that they can be moved easily from place to place. It must be possible to maintain the temperature in the heating chamber between 86° and 104° F., by means of heating apparatus which can utilize the exhaust steam. The entrance, with the staircase and the space for the barley steeping vats, comprises about 20 square yards.

The engine room should preferably be square, of sufficient size and well lighted; it should have a floor area of 11 × 9 = 99 square yards. The boiler room should be located at the gable end of the building, the potato cellar at the rear, adjacent to a longitudinal side. A ground area of 95 to 110 square yards is necessary for the latter, so that with a height of 4.5 feet about 1,000 hundredweight of potatoes can be stored in it. The Henze apparatus tower should rise above the potato cellar to about the height of the distillery roof. The yeast room should have one longitudinal wall adjacent to the warm boiler room, and should be provided with but one narrow external wall, having a single window. The boiler room should be so arranged that the fireman, besides attending to the boilers, can take charge of the distilling apparatus or the potato washer, as well. If a vehicle scale is necessary for the weighing of the potatoes furnished to the distillery, as in a central or communal plant, it should preferably be located near the engine room, so that the manager can attend to the weighing without leaving the distillery. The dwelling of the superintendent of the plant should, if possible, be located in the distillery building.

PART XIII.

THE SPENT WASH.

AFTER the alcohol has been distilled off, the spent wash remains, together with all the constituents of the mashing raw material not attacked by the fermentative action, and the non-volatile products of the fermentation. By far the greater part of the wash consists of water. The maximum limit for the water content lies between 92 and 95 per cent. Allowance must be made for this fact in using wash as fodder, in order to insure that the animals are provided with sufficient quantities of nutritive substances. The composition of the wash varies considerably; it depends upon the quantity, kind and composition of the mashing materials, upon the methods of operation and the efficiency of the distilling appliances. According to Dietrich and König, average figures for the composition of various kinds of washes are as follows:

	Potato Wash.	Rye Wash.	Corn Wash.
Water	94.30	92.20	91.32
Raw protein	1.15	1.69	1.98
Pure protein	0.80	1.36	1.91
Fat	0.10	0.45	0.93
Non-nitrogenous extractive substances	3.13	4.56	4.48
Fibers	0.65	0.66	0.83
Ash	0.67	0.41	0.46

Besides water the wash contains:

1. *The nitrogenous constituents of the mashing raw material.* In potato mashes the greater part of these, that is, about 55 per cent, comprises albuminous substances, while about 45 per cent consists of amides (asparagin). The asparagin, it will be remembered, is also available as

an excellent nutritive substance for the yeast, and in this utilization it is largely converted into easily digestible albuminous substances. It may be assumed that in consequence of this transformation of the asparagin into albuminous substances, the wash contains for each 100 parts of nitrogenous constituents about 70 to 75 parts of albuminous substances, and only about 30 to 25 parts of amides. As the nutritive value of the albuminous substances is considerably higher than that of the amides, the increase in albuminous substances through fermentation improves the degree of the food value of the wash. In grain and corn washes the quantity of the nitrogenous forms of lesser nutritive value is considerably smaller than in potato wash. According to Morgan 100 parts of the nitrogenous constituents of corn or rye wash comprise 94.2 parts of albumen and 5.8 of non-albuminous substance, while 100 parts of the same constituents in ryo wash possess similar proportions of 80.1 and 19.9. The digestibility of the nitrogenous constituents in all washes is high. Of 100 parts of the nitrogen of the wash from corn and rye, 82.5 parts are digestible, of rye wash 89.2, of corn wash 86.1, and of potato wash 82.5.

2. *The fats of the mashing raw material.* These are not attacked by the fermentation and enter the wash unchanged. Furthermore, the yeast converts certain nutritive substances in the mash into fat.

3. *Unfermented carbohydrates.* Even the most vigorous fermentation never progresses to completion; certain small quantities of the carbohydrates, consisting of maltose and, more largely, of dextrins, always remain partly unfermented. The dextrins, however, can also be easily digested and taken up by the animal organism, and must, therefore, be considered valuable nutritive substances.

4. The non-nitrogenous constituents of the mashing raw materials, which are incapable of fermentation, in-

cluding varieties of gum (pentosanes), also useful as nutritive material, enter the wash unaltered.

5. The woody fibers and the mineral substances are also found unchanged in the wash. The latter comprise chiefly potassic salts and phosphoric acid combinations; the lime so necessary for the nourishment and development of animals, on the other hand, is found in but small quantities in the wash and should, therefore, be provided in supplementary fodders.

6. Besides this, glycerine and certain quantities of acids appear in the wash, among them particularly lactic acid and succinic acid, as by-products of the fermentation. Little was known with regard to their nutritive value for a long time; lately, however, the opinion has been gaining ground that these by-products of the fermentation have a stimulating action upon the digestion, so that the wash because of the appearance of these very substances possesses a comparatively higher value especially for feeding dairy cattle, than other fodders of similar composition.

The relative nutritive values of nitrogenous and non-nitrogenous substances is the cause of the comparatively greater importance of the former in the wash, as for each part of nitrogenous substance, but 2½ to 3 parts of non-nitrogenous are present. In feeding large quantities it is unavoidable that the rations become relatively rich in nitrogen, and it is to be recommended that materials which influence this relation in favor of the non-nitrogenous substances be used for additional fodder. Such material is found in the non-nitrogenous fodders rich in carbohydrates.

Experience has shown that wash is particularly adapted for the stimulation of milk production, probably because of the presence of the by-products of fermentation mentioned above. Furthermore, it is well suited to the fattening of cattle, chiefly of beeves, though sheep, which are accustomed to fodder containing less water, do not appear to thrive so well when fed on wash. Consequently, it should be used primarily for the feeding of dairy cattle and the fattening of beeves.

It is of the greatest importance that the wash be fed to the animals in a warm condition, under certain circumstances cooked thoroughly under pressure beforehand; for otherwise, an unpleasant sickness, wash malanders, may appear, especially if the fermentation of the mash was a poor one. In column distilling apparatus the cooking is not always sufficiently carried out; in this case it is advisable subsequently to cook this wash under pressure in the montejus. It is best to introduce a steam pipe into the wash container to retard cooling to temperatures favorable to the development of injurious schizomycetes, and to be able to introduce the wash into the feeding mangers at the highest possible temperature. With the observance of these regulations, the wash is not only a safe food, but even an extremely healthful one if certain limitations in the size of the rations are observed, in order not to burden the animal organism with too large a quantity of water. It has been shown that the feed per head of large cattle should be about as follows: For fattening beeves, at the most 17½ to 18½ gallons, preferably 15 to 17½ gallons, and for dairy cattle at the most 15, and preferably 10 to 12½ gallons of wash.

Sheep should not be fed more than 1 to 1¼ gallons of wash per head. Particular care should be exercised in feeding wash to young cattle and bearing cows. The injurious action of injudicious wash feeding in the latter case appears frequently in the dying of the calves, followed by the great decrease in the dairy value of cows fed with wash. In large industrial distilleries where it is not possible to feed the wash to cattle in a fresh condition, "dry wash" is produced by drying out the water from the same. The following table gives the composition of dry wash from rye and corn respectively:

	Per cent.	Per cent.
Water	10.60	9.40
Raw protein	23.10	23.21
Pure protein	19.76	22.29
Fat	6.10	8.63
Non-nitrogenous extractive substances	42.70	45.03
Fibers	10 20	9.31
Ash	7.30	4.42

This dry wash, especially that prepared from corn, thus provides an excellent and powerful fodder, with a protein content of 23 to 24 per cent and a fat content of 6 to 8½ per cent, and almost approaches the composition of oil cake, in place of which, as a fodder, it is often employed.

PART XIV.

THE DENATURING OF ALCOHOL.

I.—THE PURPOSE OF DENATURING.

DISTILLED spirits when used as a beverage have been continuously subject to taxation in this country since 1861. The revenue derived therefrom has been enormous, and the continuance of the tax has been a matter of necessity, especially since it is a just one.

But on the other hand the tax and the consequent high price of alcohol have hindered its proper use in the arts and manufactures, and in this respect the tax has been unnecessary and unjust. It has, nevertheless, been continued because of the erroneous supposition that it was impossible to legislate so as to retain the necessary revenue-bearing tax on spirituous beverages without serious danger of fraud and reduction of revenue, caused by the illicit direct use as a beverage of tax-free alcohol, or of that recovered from articles in which it would be lawfully and fairly used duty free.

It is to overcome this difficulty that Congress by act of June 7, 1906, provided for the withdrawal from bond of tax-free alcohol, which had been mixed with suitable materials to destroy its character as a beverage, such process being known as denaturizing, or denaturing as it is to be called in this country.

In order to make this act effective, certain "Regulations and Instructions Concerning Denatured Alcohol" have been prepared by the Commissioner of Internal Revenue, acting under instructions from Congress, which are given intact in the appendix of this book. There follows here the sections describing the denaturing agents, and for sake of comparison and suggestion, a synopsis of those used in other countries.

II.—DENATURING REGULATIONS.

1.—United States.

a. Completely Denatured Alcohol.

"Sec. 26. Unless otherwise especially provided, the agents used for denaturing alcohol withdrawn from bond for denaturing purposes shall consist of methyl alcohol and benzine in the following proportions: To every one hundred parts by volume of ethyl alcohol of the desired proof (not less than 180°) there shall be ten parts by volume of approved methyl alcohol and one-half of one part by volume of approved benzine; for example, to every 100 gallons of ethyl alcohol (of not less than 180 degrees proof) there shall be added 10 gallons of approved methyl alcohol and ½ gallon of approved benzine. Alcohol thus denatured shall be classed as completely denatured alcohol.

"Methyl alcohol and benzine intended for use as denaturants must be submitted for chemical test and must conform to the specifications which shall be hereafter duly prescribed."

b. Special Denaturants.

"Sec. 79. As the agents adapted to and adopted for use in complete denaturation render the alcohol denatured unfit for use in many industries in which ethyl alcohol, withdrawn free of tax, can be profitably employed, therefore, in order to give full scope to the operation of the law, special denaturants will be authorized when absolutely necessary. Yet the strictest surveillance must be exercised in the handling of alcohol incompletely or specially denatured."

"Sec. 80. The Commissioner of Internal Revenue will consider any formula for special denaturation that may be submitted by any manufacturer in any art or industry and will determine (1) whether or not the manufacture in which it is proposed to use the alcohol belongs to a class in which tax-free alcohol withdrawn under the provisions of this act can be used, (2) whether or not it is practicable to permit the use of the proposed denaturant and at the same time properly safeguard the revenue. But one special denaturant will be authorized for the same class of industries, unless it shall be shown that there is good reason for additional special denaturants.

"The Commissioner will announce from time to time the formulas of denaturants that will be permitted in the several classes of industries in which tax-free alcohol can be used."

2.—Germany.

a. Complete Denaturing.

1. An admixture with every 100 parts by volume of spirit of 2½ parts of a mixture containing 4 parts of wood naphtha and 1 part of pyridine bases. (To this mixture 0.0065 part of lavender or rosemary oil may be added optionally to counteract the smell of the pyridine bases. But the addition is seldom made.) Spirit thus denatured is what is used for domestic purposes—heating, lighting and cooking. It is seldom used for industrial purposes. The only purpose of that kind for which its employment is considerable is the manufacture of cheap varnish.

2. An admixture with the spirit of half the quantity (viz., 1¼ parts per 100 parts of spirit) of the above denaturing mixture, together with an addition of one-fourth part of a solution of methyl violet dye and of benzene in quantities that may range from 2 to 20 parts to every 100 parts of spirit.

b. Incomplete Denaturing.

The addition to every 100 parts of spirit of either 5 parts of wood naphtha or ½ part of pyridine bases.

c. Special Denaturants.

The quantities of the denaturing agents referred to below are to be added to each 100 parts of alcohol.

1. For the production of brewers' varnish and similar substances: 20 parts by volume of a shellac solution, which is made by adding 1 part by weight of shellac to 2 parts by weight of spirit of at least 90 degrees, are added to the spirit.

In this case the alcohol in the shellac solution, if made under official supervision, is also allowed exemption from duty.

2. For the production of celluloid and pegamoid: 80 parts by weight of camphor, or 2 parts of turpentine or ½ part of benzene, both by volume.

3. For the production of the following substances:

(a) Ether, ordinary (with certain limitations and regulations as to sale and use); (b) ethyl sulphuric salts; (c) agaricin, podophyllin, scammony, guiacum and jalap resins, as well as other resins and gum resins; (d) aldehyde and paraldehyde; (e) white lead and acetated lead; (f) ethyl chloride, bromide and iodide; (g) photographic paper and dry plates, and emulsions of chloride, bromide and iodide of silver and similar preparations; (h) chloral hydrate; (i) electrodes for electric storage batteries; (j) acetic ether (with certain limitations as to sale and use); (k) glucosides; (l) rubber preparations; (m) collodion, and bromide, chloride and iodide of silver emulsions of collodion; (n) pancreatin, alkaloids, santonin, tannin, and salicylic acid and its salts; (o) coal tar colors, including substances used in obtaining them, and intermediate products; (p) chemical preparations (not otherwise named) which do not retain any spirit when finished (except formic ether and valerianic ether and butyric ether): 10 parts of sulphuric ether, or 1 part of benzene, or ½ part of turpentine, or 0.025 part animal oil, all by volume.

Collodion for sale must contain at least 1-100 of its weight of gun-cotton.

4. For the preparation of chloroform: 0.003 part by weight of chloroform.

5. For the production of vinegar: Two hundred parts by volume of vinegar containing 3 per cent acetic acid, or 150 parts vinegar containing 4 per cent acetic acid, or 100 parts vinegar containing 6 per cent acetic acid and 100 parts of water and so on; or 50 parts vinegar containing 12 per cent acetic acid and 100 parts of water; or 30 parts vinegar containing 6 per cent acetic acid and 70 parts of water, and 100 parts of water.

Any excess of the quantity of acetic acid in the vinegar mixture or of the spirit is to be allowed for, and the water may be replaced entirely or in part by an equal quantity of beer, glattwasser, or natural wine.

6. For making inks, sealing wax and stamping inks: 0.5 part by volume of turpentine, or 0.025 part of animal oil.

7. For making bedstead enamels and brewers' varnish, as well as for use in incandescent lamps, for finishing silk ribbons and for cleansing jewelry, etc.: Five-tenths part of turpentine.

8. For making iodoform: 0.002 part by weight of iodoform.

The iodoform may be dissolved in part of the spirit, and the solution then added to the remainder of the spirit.

9. For varnishes and polishes of all kinds: Two parts by volume of wood spirit and 2 parts petroleum benzine, or 0.5 part of turpentine.

Polishes and varnishes not for use in the works of the makers, but for sale, must contain at least 1-10 part of their weight of shellac or other resin.

10. For preparing medical, botanical and zoological preparations for educational purposes: One part (commercially pure) methyl alcohol, and 1 part petroleum benzine.

11. Soap making: 1¼ parts by weight of castor oil and 0.625 part of soda solution.

The denaturing materials may be dissolved by heating in part of the spirit, and the solution then added to the remainder of the spirit.

12. For the production of wool fat (lanolin): Five parts by volume of petroleum benzine.

3.—England.

a. Complete Denaturing.

Completely denatured alcohol is known as "mineralized methylated spirit" and it is only in this spirit that retailers are permitted to deal. It is made by adding to 9 parts of grain alcohol (which must be at least 50 per cent above proof) 1 part of wood naphtha. To this mixture is added 0.375 per cent of mineral naphtha (petroleum).

b. Incomplete Denaturing.

This is known as ordinary methylated spirits, and can be purchased only for manufacturing operations and from a methylator. It consists of 9 parts of grain alcohol to 1 of mineral naphtha as above.

c. Special Denaturants.

Special processes appropriate to particular industries and approved by the Board of Inland Revenue.

4.—France.

a. Complete Denaturing.

The official denaturant at the present time is 10 parts of methyl spirit and 0.5 part of standard benzine, which are to be added to every 100 parts of grain alcohol. This latter must test at least 90 degrees strength and not contain more than 10 per cent of essential oils, amyl alcohol, etc. The methyl spirit must test 90 alcoholometric degrees and must contain 25 per cent of acetone and 5 per cent pyroligneous impurities which impart a pungent smoky odor to the spirits. The standard benzine is a distillate from coal tar coming over between 300° and 325° F. Therefore, it is a complex body, but is always of about the same composition.

b. Incomplete Denaturing.

Under this head may be classed the so-called carbureted alcohol, which is now used extensively for internal combustion motors. In this, 30 to 50 per cent of benzine is mixed with grain alcohol, which mixture is found to give the best results in automobiles, small motors, etc.

c. Special Denaturants.

1. Varnishes and Dyes (Tinctures) for Varnishes.

Mix with alcohol of 90° or above, at the temperature of 150° F. (without correction), 15 per cent of methyl spirit conformable to the regulation type.

2. Alcohols for the Clarification or for the Finishing of Varnishes.

Mix with the alcohol of a strength equal or superior to 90°, 15 per cent of regulation methyl spirit and 4 per cent at least of resin or of gum resin.

3. Insect Destroyer.

Mix with alcohol 15 per cent of methyl spirit. The product of the mixture shall be transformed on the place into a finished product.

4. Simple or Compound Ethers.

Make an intimate mixture of the alcohol to be methylated with 10 per cent of its volume of residue of ether.

5. Bromhydric Ether.

Mix 7.5 parts by volume of spirit of 93° with 8.5 parts of sulphuric acid of 66° and 0.015 part of bromine, with allowance to modify this proportion to the extent of 10 to 15 per cent.

6. Hydriodic Ether.

Mix 5 parts by weight of spirit at 96°, 4 parts of iodine, and 0.8 part of amorphous phosphorus.

7. Ethylate of Soda.

Mix 6.3 parts by weight of absolute alcohol and 0.5 part of sodium.

8. Nitric Ether.

Mix one part by weight of nitric acid of 36° and four parts of alcohol of 96°.

9. Chlorhydric Ether and Derivatives.

Mix equal weights of alcohol of 96° and hydrochloric acid of 21°.

10. Aldehyde.

Mix with alcohol of whatever degree 10 per cent of sulphuric acid of 66° Baumé, or 20 per cent sulphuric acid of 54°, taking care that the temperature of the mixture be brought up to 176° F. during the longest time that it will be possible for the officials to give to it.

Pour the mixture over bichromate of potassium (which should be exclusively employed as oxidant) after the rising of the temperature which is produced has completely ceased.

11. Alcohols for the Use of Dyers or of Manufacturers of Colors, and Methylated by These Tradesmen.

Add to the alcohol 15 per cent of its volume of methylene conformable to the regulation type. The product of the mixture is to be used in the factory where the mixture has been made, for dyeing or for the manufacture of colors. It can not be admitted to circulation outside the factory.

12. Tannins and Different Alkaloids.

Add to the alcohol 15 per cent of its volume of methyl spirit conformable to the regulation type. The product of this mixture shall be transformed on the place into finished products.

13. Fulminate of Mercury.

Mix previously alcohol with 15 per cent of its volume of wood spirit conformable to the regulation type.

14. Alcohols for Lighting and for Heating.

To 100 parts by volume of alcohol of 90° add (1) 15 parts of methyl spirit, (2) 0.5 part of heavy benzine, and (3) 0.00001 part of green malachite.

15. Transparent Soaps.

Mix with the alcohol 15 per cent of wood spirit conformable to the type.

These mixtures shall be employed on the place; they are not to be circulated outside of the establishment where they have been made.

16. Chloral and Chloral Hydrate.

Let pass over the alcohol a current of chlorine gas, which from the first moments on determines the formation of numerous products by which the production of the chloral is accompanied—aldehyde, chlorhydric acid, chlorhydric ether, etc. The manufacturer shall produce for each part of alcohol of 95° a quantity of chlorhydrate, which shall not be less than 0.78 part.

17. Collodion.

Mix the alcohol with its volume of ether; add to the mixture the pyroxylin, and, in case the use of the collodion is to be immediate, the iodures, bromures, etc., which transform it into a commercial product.

18. Liquid Rennet.

The alcohol employed for the manufacture of liquid rennet can be considered as sufficiently methylated by its dilution with brine, upon condition that the alcoholic degree of this dilution does not exceed 10°. In default of this process, or of an analogous process, the methylation should be effected by the addition of 15 per cent of methyl spirit.

5.—Sweden.

The common denaturing agent is composed of 10 parts of wood spirit and 3 parts of pyridine bases. The wood spirit must contain more than 30 per cent acetone and not less than 1 per cent or more than 1½ per cent of substances that decolorize bromine solution.

PART XV.

ALCOHOL FOR THE PRODUCTION OF POWER.

THE use of alcohol as a motor fuel, that is, as the explosive agent in an internal combustion motor, is a purely modern development of engineering practice. Until 1897 the attempted utilization of spirit for the production of motive power was attended with very little success, owing to ignorance of the conditions best suited to effective operation. Among the first to demonstrate the feasibility of the spirit as a fuel was Ringelmann, who made an extensive series of investigations at the Experimental Mechanical Laboratory of Paris. During the past decade many prominent engineers, particularly in Germany and France, have vigorously prosecuted research work along similar lines, and, together with experimenters in practice, have thoroughly demonstrated that alcohol, when produced cheaply, can be used with distinguished success in internal combustion engines. As a fuel, spirit possesses many advantages over its more dangerous competitor, gasolene. It may be said in general, that as a power-producer alcohol is little inferior to the latter, though it must be conceded that with present explosive motor designs and the means at hand, it is more difficult to start an engine using alcohol than one using gasolene. It may be said with truth, however, that this difficulty will doubtless soon be overcome, for once the engine builder is given the incentive to perfect the design in this regard, he will soon accomplish the production of an engine in which this disadvantage is avoided.

Alcohol is unquestionably less dangerous to use than gasolene, which is so terribly inflammable that laws forbidding its sale or even decanting after nightfall are in force throughout the country. Burning gasolene cannot be put out by means of water, as the oil floats upon the latter, which but tends to spread and increase the flames. Alcohol, on the other hand, being miscible with water in all degrees, can, when ignited, be instantly quenched by means of water. With alcohol, too, there is no need for a law preventing its handling, decanted, after dark. The vapor of alcohol is not inflammable unless closely confined, and naked lights can be used about an alcohol engine with impunity. The only danger from a leak lies in the loss of the alcohol, or in the possibility of a slow fire, which can be put out easily, should a flame come into actual contact with the liquid. The odor, arising from the exhaust gases of a gasolene engine are unpleasant, to say the least, and in this feature, too, alcohol is far superior to the other fuel in that the odors which result from its combustion are almost imperceptible, and, when noticed not unpleasant. Of course, there is the possibility that the denaturing agent may cause an unpleasant smell to arise from the combustion of the alcohol, though, practically, little need be apprehended in this regard. Cleanliness of combustion is an extremely attractive feature in the use of alcohol. Cylinders and valves are not clogged by residual products, and it would appear that a better two-cycle engine could be designed for alcohol than for gasolene, because of the cleaner combustion of the former.

The German, French, Austrian, Russian, and other European governments have given every encouragement to investigators in order to extend the field of the utility of alcohol in this, as well as in other directions. Alcohol expositions are held annually and prizes are given for special researches tending to increase existing knowledge of effective methods of utilization. Under the influence of careful supervision, and with the aid of scientific methods, these researches have borne results of great importance in the development of the use of alcohol as a fuel. Should our own government find it possible to pursue a like plan the results would unquestionably be similarly gratifying on this side of the Atlantic, and the idea would doubtless be heartily recommended by men in scientific and engineering circles throughout the country.

Naturally enough, the United States has played no part in the engineering and commercial development of alcohol as a fuel; for the prohibitive tax with which the spirit has hitherto been burdened rendered its application to motor appliances impossible, and so, while our European competitors have been progressing with rapid strides in this field of endeavor, our only advances along similar lines have been the profit we have drawn from foreign investigations. Until lately even our literature upon the subject has been marked by the conspicuous absence of practical data. We have been dependent upon the investigations of European engineers for information regarding alcohol motors, that is, engines in which alcohol can be utilized. Our manufacturers are hardly prepared to fill a possible demand for this type of motor, and our engineers can scarcely be said to possess the practical knowledge necessary for the most economical and efficient operation of these engines. As mentioned before, the researches of foreign engineers, particularly of the Germans, are, of course, available, but it is extremely difficult to draw proper deductions from arbitrary sets of figures representing efficiencies or comparative economic values, without a full knowledge of the conditions under which these tests were made.

This state of affairs, of course, exists in the case of any similar motor element, and it is generally acknowledged that the results of carefully executed scientific tests are often valueless in practice, because the conditions under which the tests were carried out are seldom duplicated at other times. For instance, it is generally accepted in regard to gasolene engines that an economical motor will burn about a pint of gasolene per hour per horse-power. Certain engines require as little as 8/10 of a pint, though with poor valve setting, improper fuel, or under other unfavorable circumstances, the amount can easily be run up to 3 or 4 pints per hour per horse-power. In comparative tests one engine may be running under the circumstances best suited to it, while the other may be operating under conditions which are decidedly unfavorable to its best performance. Thus, unless we are thoroughly familiar with all the circumstances and conditions under which tests were carried out, it is with caution that we must accept arbitrary values in regard to the comparative efficiency of gasolene and alcohol engines.

This much, however, can be said with regard to the latter: Given the spirit at anything like the price claimed by its advocates, and alcohol will provide us with a fuel peculiarly well adapted for many cases of small power production. While we cannot question that the high efficiencies obtained by certain investigators are possible, we cannot know whether they are obtainable in practice. Doubtless, however, it will be found that alcohol is little inferior to gasolene, so that, if cheaply produced, it can be used to advantage for certain motor purposes, the entire question devolving upon whether or not it is possible to obtain the fuel at low enough cost. To utilize it to the best advantage in explosive engines, special motors will have to be produced, notwithstanding that it has been shown in foreign practice that the same engine can use either alcohol or gasolene without losses as great as it has sometimes been alleged. The specially constructed engine is the proper agent to use for high economy, and its development will doubtless soon follow the wider use of the alcohol fuel. The real gain in using alcohol is ultimately in the fact that it is the employment of material which can be reproduced in the cycle of the seasons, instead of drawing upon the stored energy of the earth, which is so rapidly being depleted. Alcohol possesses another great advantage in that the explosive mixture can be used under far higher compression, without auto-ignition, than gasolene, an explosive mixture of which will not stand high compression. That this fact is of importance in diminishing the effectiveness of the latter fuel is well known. The alcohol explosive mixture will stand a far higher degree of compression, and when the alcohol is hydrated the compression can be carried still further, so that a very large percentage of the heat energy of the poorer mixture is converted into useful work.

It has been assumed, particularly by engineers not especially familiar with the fuel action of alcohol, that it was far less economical for motive purposes than gasolene, because of its lower thermal efficiency. However, it has been proven that alcohol mixed with water is a better fuel than pure alcohol, and this fact thoroughly substantiates the view that the fuel which has a lower thermal efficiency may sometimes be as effective in use as one of higher thermal value. In practice, it is the number of heat units converted into useful mechanical work, and not the total number of heat units available, which determines the value of a fuel. The thermal efficiency of explosive motors increases with the decrease of temperature produced by the explosion, provided the explosive pressure remains constant. Notwithstanding that this theory has been completely demonstrated by experiments, it would appear erroneous, as heat is the origin of power, and it would seem that with a lower temperature the power must also be reduced. The anomaly is apparent only in the case of an explosion motor working on what may be called a superheated cycle.

In conclusion, we may sum up the advantages of alcohol for fuel purposes as follows: First, freedom from danger; secondly, absence of disagreeable odors; thirdly, capability of high compression; fourthly, low initial heat and discharge of exhaust gases at relatively low temperatures; fifthly, character of the explosion, which is less sudden and more prolonged; sixthly, more perfect ignition and combustion.

As little is known regarding the arrangement of the atoms entering into the composition of alcohol, it is impossible accurately to compute the heat value from the chemical composition, and therefore recourse must be had to the calorimeter. Various experimenters have found the heat value of alcohol to lie between 13,310 B. T. U. and 11,664 B. T. U. per pound, the latter value being the one most generally used. One gallon of pure alcohol having a specific gravity of 0.7946 at 59° F., has a corresponding heat value of 77,274 B. T. U. In accordance with the chemical composition, 1 pound of absolute or 100 per cent alcohol requires 9 pounds of air, or 111.5 cubic feet at 62° F. for complete combustion. The heating values of commercial alcohols are almost always lower than that of absolute alcohol, as water in greater or less quantity is generally mixed with the ordinary spirit obtainable. The heating values vary from 10,880 B. T. U. for 95 per cent alcohol, having a specific gravity of 0.805, to 7,200 B. T. U. for 70 per cent alcohol having a specific gravity of 0.856.

Benzene, C_6H_6, which enters largely into denaturing methods, is often mixed with alcohol in larger quantities in order to increase the heating value of the fuel mixture. Benzene has a specific gravity of 0.866 and a heating value of about 17,200 B. T. U. per pound. From 10 to 40 per cent of the benzene is sometimes employed, thus raising the heat value of the fuel, and at the same time decreasing the cost per heat unit, that is, the specific heat cost. If the combustion of alcohol is effected with insufficient air supply, acetic acid is formed among the products of combustion, and this causes rusting of the engine parts. While this danger can easily be avoided by providing the necessary air, it is an additional safeguard to use benzene mixed with the alcohol. Benzene, however, possesses a disadvantage in that its use sacrifices to some extent the advantages possessed by the alcohol in its odorless exhaust.

I.—COMPARATIVE EFFICIENCIES OF GASOLENE, KEROSENE, AND ALCOHOL MOTORS.

The values given below are the results of tests made by Prof. Eugen Meyer for the German Agricultural Society. While the results obtained were uniformly excellent they have doubtless been bettered since by improvements in the design of the motors, especially with regard to increased compression. In the comparative efficiency and cost values deduced by Meyer, he assumed the average price of gasolene to be 15 cents per gallon, and that of kerosene, 13 cents. The conditions to-day are materially changed, and it is practically impossible to obtain small quantities of good gasolene for less than 20 cents, and furthermore, because of the increasing demand, the price is constantly rising. This would tend to make the use of alcohol still more favorable. On the other hand, Meyer's assumption that alcohol could be sold for 15 cents a gallon, would most assuredly not apply to the United States; for the question of cost is here still an open one, and it is still doubtful whether it will be possible to place fuel alcohol upon the market at less than 20 cents. As a matter of fact, in Germany to-day, the price of alcohol is 29 cents per gallon. For purposes of comparison, however, the values given may be used, but, as we are unfamiliar with the circumstances and conditions under which the tests were carried out we cannot say whether or not these performances can uniformly be repeated in practice.

At the fuel costs assumed, the following table gives the cost, in cents, for 10,000 B. T. U. with each of the three fuels.

Fuel.	Heating Value, per pound. B. T. U.	Cost per Gallon. Cents.	Cost per Pound. Cents.	Specific Gravity.	Cost of 10,000 B. T. U. Cents.
Gasolene	19,000	15.0	2.57	0.710	1.35
Kerosene	18,500	13.0	1.88	0.800	1.02
Alcohol, 90 per cent	10,080	15.0	2.21	0.815	2.19

It can be seen from the above that 10,000 B. T. U. from alcohol are much more expensive than the corresponding values for gasolene and kerosene. In order to equal in cost of operation that of the other fuels, the thermal efficiency of the alcohol engine must be 1.62 times as great as that of gasolene, and 2.15 times as great as that of the kerosene engine, all other losses being the same. The thermal brake efficiencies given in the table below are the best figures obtained by Diesel in 1903 for gasolene and kerosene engines, allowance being made for improvements in engine construction and fuel utilization since that time. Diesel's figures for the gasolene engine and the kerosene engine were respectively 20.5 per cent and 17.6 per cent. The best figure obtained by Meyer in 1902 for thermal efficiency in the competitive tests of ten alcohol engines, was that of the Deutz engine, 31.7 per cent. In this case the end compression was 190 pounds per square inch, while that of the explosion exceeded 450 pounds. Though it is possible to increase even this high efficiency by the use of still higher degrees of compression, it is not advisable to introduce them into average practice, as extremely high compression renders the engine unproportionately sensitive to improper setting of the inlet valve. Under these conditions the maintenance and care of the engine is rendered far more difficult, and even with the best of care unsteady and erratic operation is liable to ensue. Benzene and alcohol mixtures are not taken into consideration, as, in general, the thermal efficiencies approximate those of alcohol alone. The use of much benzene is not to be recommended, as it tends to foul the engine. The following table gives the economy and cost figures deduced from Meyer's tests. They are not to be regarded, however, as determining with exactitude the comparative efficiency values of gasolene, kerosene, and alcohol; for, as mentioned above, it is hardly proper to determine such comparative values from sets of arbitrary figures, where exact knowledge of the conditions obtaining is not at hand:

Fuel.	Cost for 10,000 B. T. U. Cents.	Best Consumption of Fuel per B H P. Hr Pound	Best Thermal Brake Efficiency Per Cent	B. T. U. per B. H. P. Hr.	Fuel Cost per B. H. P. H. Cents.
Gasolene	1.35	0.580	23.0	11,000	1.485
Kerosene	1.02	0.725	18.0	11,140	1.442
Alcohol 90 per cent.	2.19	0.803	31.7	8,030	1.758

From the above table it would appear that the operation with alcohol, 90 per cent pure, costs 19 per cent more than with gasolene, and about 22 per cent more than with kerosene, and, on the basis of the above computations, 90 per cent alcohol would have to cost 12 cents a gallon to be on a par with gasolene. Thus we see that gasolene is still in advance of alcohol as regards fuel costs, but it may be said, that with the advancing price of the former, the decreasing price, it is to be hoped, of the latter, and improvements in the design of alcohol engines and the methods of alcohol fuel utilization, the use of alcohol in motors will become far more general; for regardless of fuel cost it possesses many advantages over gasolene for this purpose. This is the real reason why alcohol has found such extended application in certain European countries, in spite of its somewhat greater operating cost.

II.—THE ALCOHOL MOTOR.

The alcohol engine does not differ materially in detail from the ordinary gasolene engine, and, as a matter of fact, any gasolene engine can run on alcohol and any alcohol engine can be made to operate with gasolene, provided proper means be used for suitably making the fuel mixture in each case. The efficiency of operation of alcohol engines can be materially increased by increasing the compression, within proper limits. The difference in compression, and the difference in the vaporizer or carbureter are the main distinguishing features in the two types of motors. The latter difference is the one of greater importance.

As so little has been done in this country with the question of the development of alcohol motors, we must turn to Europe for information regarding the best type of engine to be used. In Germany, especially, have numbers of excellent motors been developed, and the accompanying illustrations are of German engines of this type. As alcohol is less volatile than gasolene, though presenting less difficulty in this respect than kerosene, the agency of heat is used in nearly all of the vaporizing devices now on the market. As a rule, the exhaust heat of the gases of combustion is utilized, though this method has the drawback that the heat is not available at the start when the engine is cold, and it has been found in practice to be almost impossible to start a cold engine on alcohol alone. In most cases the engines are started with gasolene to avoid the use of an open flame to heat the vaporizer at the

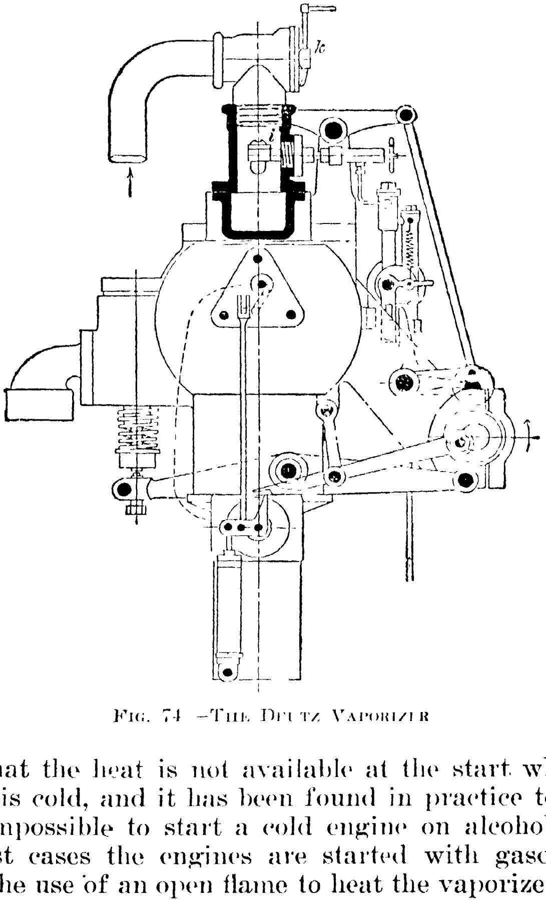

FIG. 74.—THE DEUTZ VAPORIZER

start, as this is both dangerous and cumbersome. After a few strokes with the gasolene mixture, enough heat is available for the purpose of vaporizing the alcohol, and the change is usually effected by throwing over a single lever. In most of the designs of this kind but a few minutes need elapse before the change to alcohol can be made. It must be said, however, that the use of gasolene, either to start with or in a torch, brings with it the very disadvantages of danger and smell, at least at the start, which are objected to in this fuel.

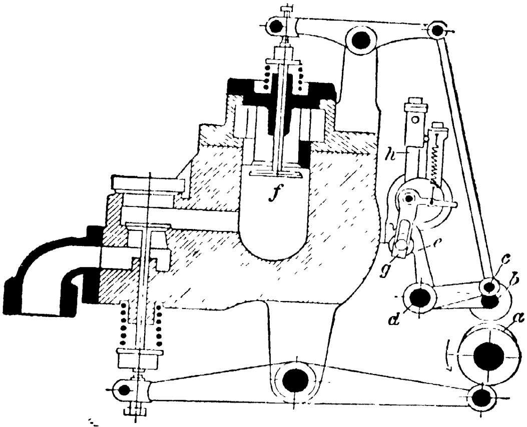

FIG. 75—THE DEUTZ VAPORIZER.

The vaporizers for alcohol are substantially of three types, based upon the manner of heating. They comprise first, those in which no heat is employed; secondly, those in which the air is pre-heated; and lastly, those in which the mixture is heated and then superheated.

The Deutz vaporizer with which such excellent results were obtained in Meyer's tests, is illustrated in Figs. 74 and 75. The engine is governed by throttling, the inlet valve *f* being actuated by levers and the cam *a*, which is of taper form, with *f* under the control of the governor. The duration of the time during which the valve is open depends upon the position of *a*. The cam also acts upon the plunger of the fuel pump *h*, through the bell

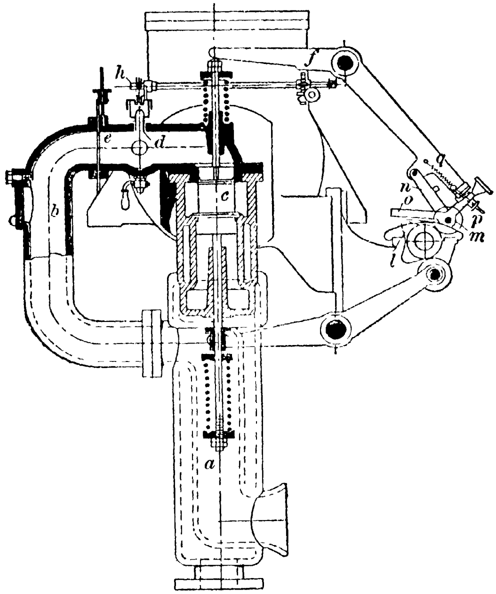

Fig. 76.—The Altman Vaporizer.

crank, *c*, *d*, *e*, the action being one of suction during the first part of the movement, and of pumping the liquid during the latter part. In consequence of this arrangement, the fuel is injected during the second half only of the suction stroke, thereby insuring a rich mixture at the igniter. The current of air enters through the valve *k* and is enriched by the alcohol which is forced through the atomizer *i*. Thus, there is no pre-heating notwithstanding the thoroughness of the atomization. To avoid throwing down the vapor, the ports of the cylinder are as direct and short as possible. It has been found that no pre-heating of air or fuel mixture is necessary when the engine is regulated by the throttling method instead of by the hit and miss systems. This is undoubtedly due to the fact that in the latter an engine under less than normal load is cooled at the cylinder during a succession of misses, so that part of the alcohol vapor on the next explosion is thrown down unless it is superheated.

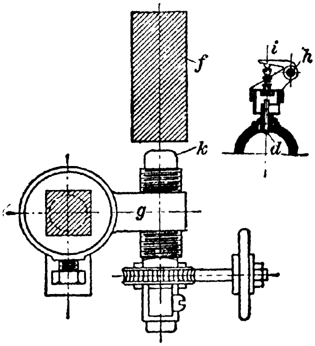

FIG. 77.—DETAIL OF ALTMAN VAPORIZER.

In the Altman vaporizer, shown in Fig. 76, the air is pre-heated. A regulating valve for the air is provided at *e*, the air pipe *a*, *b*, being surrounded at its lower end by the exhaust pipe. The arrangement of the regulating valve is such that when it is drawn upward the amount of air passing through it is decreased, but always in such a manner that the current strikes through the upper part of the pipe and is directed against the fuel nozzle *d*. The valve lever *f*, which operates the fuel valve *d* through a reach rod and the finger *h*, *i*, shown in Fig. 77, operates the inlet valve *c*. The lever *f* is actuated by the cam *l*, through a pendulum hit and miss governor *o*, *m*, *p*. As shown in Fig. 77, the lever *f* forces down the point of the screw *k* when it is depressed. It thus turns the reach rod about its axis and depresses the point *i* to open the valve *d.* The position of the screw *k*, which can be very finely adjusted by the worm and wheel arrangement shown, regulates the amount of the opening of the valve *d.* In this system the fuel supply is partly atomized by the current of air, and is subsequently completely vaporized by the heat in the pre-heated air.

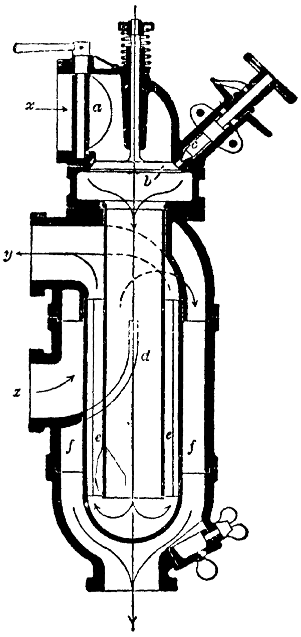

Fig. 78.—Dürr Vaporizer.

In Fig. 78 is illustrated the Dürr vaporizer, which produces a highly heated mixture, and is of the third classification mentioned above. In this construction, the regulation of the air which enters at *x* is effected by the throttle valve *a*, the inlet valve *b* being automatic. Alcohol is supplied through the needle valve *c*, which is so arranged that when *d* is closed, no fuel can enter. The mixture passes through the tube *d*, and returning through the annular space *e* surrounding the tube *d*, enters the cylinder at *y*. The exhaust gases which enter below *y* through the opening *z*, are forced by means of baffle plates to take a path through the space *f* surrounding the annular space *e*. The space *e* is further provided with a number of metal spirals joining the outside wall of *e* with the inside, and thus presenting a large heated surface to the passing charge and facilitating the transfer of heat from *f* to *d*. This vaporizer furnishes a more highly superheated mixture than any of the others, in consequence of the fact that every possible way of thoroughly utilizing the heat of the exhaust gases is employed.

In contradistinction to the type above is the vaporizer illustrated in Figs. 79 and 80, which is constructed by the Dresdener Gasmotorenfabrik. It embodies a novel principle whereby the cooling water of the engine, after being heated by the radiation of the cylinders, is used for heating the mixture. The warm water enters the jacket of the vaporizer at *x*, while air enters at the top at *y*. The inlet valve *b* is automatic, though at the start it can be pushed down at will by means of the projecting stem *c*. The fuel valve *d*, to which the alcohol is fed through the needle valve *e*, is opened by the downward movement of the inlet

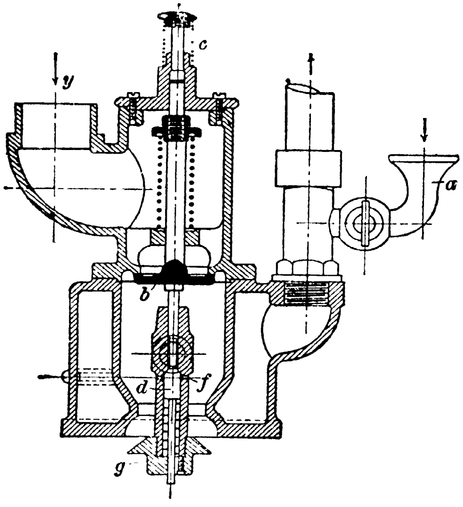

FIG. 79.—DRESDENER VAPORIZER.

valve. The alcohol enters the air current through a number of fine openings, and is carried along with it. The cone *g* against which the current strikes, assists in the thorough mixing of the gases. On very cold days the vaporization may be assisted at the start by pouring hot water into the funnel *a*. The heating in this vaporizer is not of a very high degree, for not only is the jacket water comparatively cool, but the mixture also does not remain in the heating chamber for any considerable period.

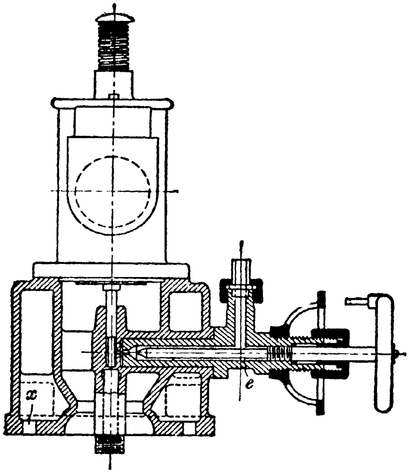

FIG. 80.—DRESDENER VAPORIZER.

It has been said that the form of vaporizer likely to come into most general use is that known as the double float carbureter, shown in Fig. 81, and used on the Marienfelde motors. This form of vaporizer is provided with two similar chambers, *a* and *b*, one being used for gasolene, and the other for alcohol. The needle supply valve of each chamber can be held shut by the springs *c* and *d* respectively. The chamber *a*, containing gasolene, is used on starting the engine, the spring *c* being pushed aside so that the fuel can flow; the latter is maintained at constant level by the float. The two-way valve *g* is so set that the path for the air from *h* past the gasolene nozzle at *c*, and through *g* into the cylinder, is open. At every suction stroke the air current drawn in is charged with gasolene, which issues in a small jet from *e*. When the cylinder has been sufficiently heated the change to alcohol is made, the spring *c* being pushed into place while the spring *d* is forced aside, and the valve *g* is turned into the position shown in the illustration of this type of vaporizer. The air supply in this vaporizer is heated in the usual manner by means of the exhaust gases. Fig. 82 illustrates a two-cylinder marine alcohol engine of the Marienfelde type, and as can be seen from the engraving, it does not differ materially in design from that of a

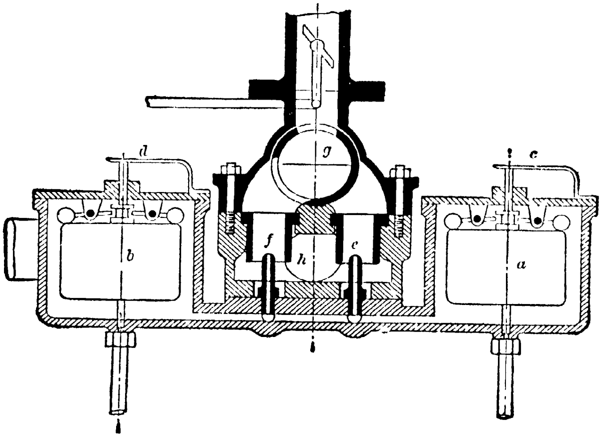

FIG. 81.—MARIENFELDE VAPORIZER.

gasolene motor, with the exception of the carbureter and the compression chamber. The tank *a* which contains the alcohol is maintained at a certain pressure by means of the exhaust gases, which force the alcohol into the proper float chamber of the last-described type of vaporizer. The

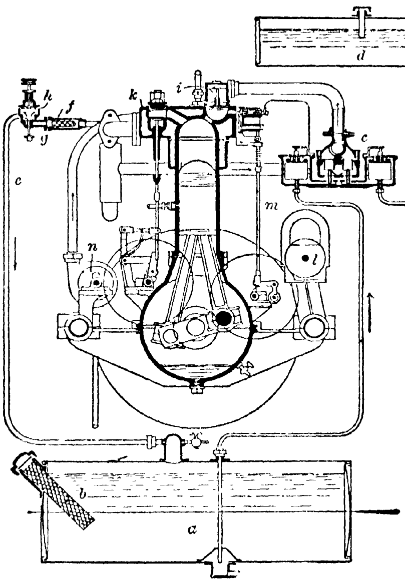

FIG. 82.—MARIENFELDE ALCOHOL MOTOR.

inlet valve *i* is automatic; the exhaust valve *k* is mechanically operated. The fresh air for the fuel mixture passes through a heater surrounding the exhaust pipe, and is thus pre-heated on its way to the vaporizer, the volume of the pre-heater being 12 to 15 per cent of the stroke volume of the cylinder. The ignition is by means of the magneto device *l*, *m*, and is of the make-and-break type.

The motor is governed on the hit-and-miss system. The circulating jacket water is kept in motion by a small rotary pump *n*. The gasolene necessary for starting the motor is kept in the tank *d*, at a higher level so that the fuel is supplied to the gasolene chamber of the vaporizer by gravity.

PART XVI.

HEATING WITH ALCOHOL FUEL.

ALCOHOL, be it pure or denatured, is in many respects superior to kerosene and gasolene for the heating of rooms and of cooking and other household utensils. The extent and the manifold ways in which petroleum products and gas are used for such purposes is well known and need not be dwelt upon. This use results from the fact that fire so produced can be easily started and extinguished instantly, and the heat can at all times be regulated as desired. The stoves are cleanly in that there are no ashes or dust, and being light and not attached to flue or chimney, they can be easily moved from place to place. Moreover the initial cost and the operating expense are less than with a coal stove, and there is a great saving in time and in fuel, generally. These unquestionable advantages have made oil and gas stoves very popular and their use widely extended.

Alcohol can be used in almost any stove which burns gasolene, and in a "blue flame" kerosene stove with little or no change it has all the advantage just enumerated. As a household fuel it has many additional ones. It is safer, as has already been explained; the accidental fire can be extinguished with water, whereas kerosene and gasolene fires are spread thereby. Alcohol is not greasy by nature, nor can there be any disagreeable odor attending its use. The flame is at all times non-smoking, as well as odorless, and thereby is rendered especially desirable for cleanly cooking, particularly for broiling. The kitchen utensils are never blackened by the alcohol flame, and time and labor are saved by this fact, too.

All of these advantages can be plainly seen in a simple comparative trial of the two fuels. Advantages not so easily observed, but which are none the less real and important, are found in the increased healthfulness and purity of the air of a closed room in which an alcohol stove is burning, as compared with one containing a kerosene or gasolene stove. The noxious influences of carbonic acid gas in rooms, and the measures which are nowadays taken to maintain in all rooms an atmosphere as free as possible from this deleterious gas are well known. That carbon monoxide gas always accompanies this and is many times more poisonous and more lasting in its evil effects, is not so well known. This gas results from the incomplete combustion of carbonaceous materials, and the very fact that the alcohol flame is non-luminous shows that combustion is more complete, and that there is therefore less of the extremely poisonous carbon monoxide formed than in the combustion of kerosene and gasolene. Moreover the chemical composition of petroleum products shows that on an average they contain 85 per cent of carbon, while the 90 per cent alcohol, which is generally used, contains but 44.6 per cent of carbon. Simple chemical calculations show, therefore, that from the burning of one part by weight of petroleum products 3.12 parts of carbon dioxide gas are formed, and of alcohol 1.63 parts, only about half as much. A larger part of the heating value of alcohol than of petroleum comes from the combustion of the gaseous element hydrogen, which produces a hotter flame and no noxious combustion products, but only water. Alcohol should be used, therefore, whenever possible for heating, because it produces far less carbon dioxide and deadly carbon monoxide than petroleum products.

I.—ECONOMY OF ALCOHOL FUEL.

Alcohol, it may be expected, will soon cost about the same as gasolene and but a trifle more than kerosene weight for weight. At the price given in the previous Part XV., the relative costs of equal amounts of heat theoretically given off by these three are:

Gasolene	1.35
Kerosene	1.02
Alcohol	2.19

The apparent superior economy of petroleum products in theory is not borne out in practice. There are greater heat losses from the gasolene and kerosene flames than from the alcohol flame; the latter, because it contains no solid incandescent carbon, does not radiate heat so much. These facts and others of a purely technical nature, combine to make the cost of alcohol heating only about one-fifth more than that of kerosene or gasolene for equal heating effects. This slight difference in cost which may soon be changed to the favor of alcohol by its cost falling below that of the others, is more than compensated by the advantages just mentioned. It has not sufficed to hinder the widespread use of spirit for such purposes in Europe.

II.—THE NATURE OF THE FUEL.

The denaturing of grain alcohol with small amounts of wood alcohol and benzene, as the United States regulations prescribe, in no way interferes with its value as a fuel; it is necessary only that the denatured alcohol should correspond to at least 90 volume per cent pure alcohol, and should not be denatured with any solid substance. In France a solid material called malachite green was used in small amounts as one of the denaturants. It gradually accumulated in wicks and burners, befouling them and lowering the efficiency of the devices.

In this connection a novel form of alcohol fuel, called Smaragdin, which has recently been introduced abroad, may be mentioned. It is solid and comes in small cubes

FIG 83 - SOLID ALCOHOL—ALCOHOL, ETHER AND GUN COTTON.

about one-third inch in size, and consists principally of alcohol with the addition of a little ether, which together dissolve a small amount of gun cotton. This sets to a jelly-like solid, which will keep for a year or more in a closed vessel, with little loss by evaporation. A heap of this "solid alcohol" is illustrated in Fig. 83, and in Fig. 84 a few pieces of the same are seen burning in an open, shallow dish. Of course the alcohol quickly evaporates on exposure to the air. This form of fuel is easily carried in small amounts and can be used for heating

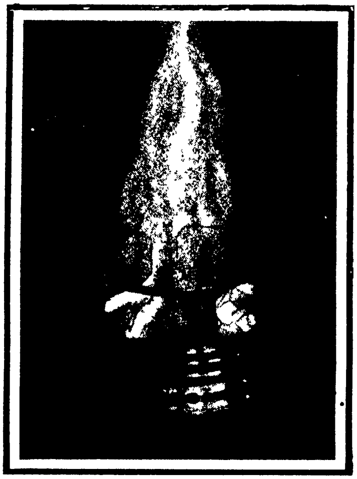

FIG. 84.—SOLID ALCOHOL BURNING IN AN OPEN VESSEL.

where no alcohol burner is available, for it can be burnt in any non-combustible receptacle, or can be used as ordinary alcohol. It burns quietly and leaves almost no residue. In Germany, one-half pound, equal to about half a pint of alcohol, costs approximately 35 cents.

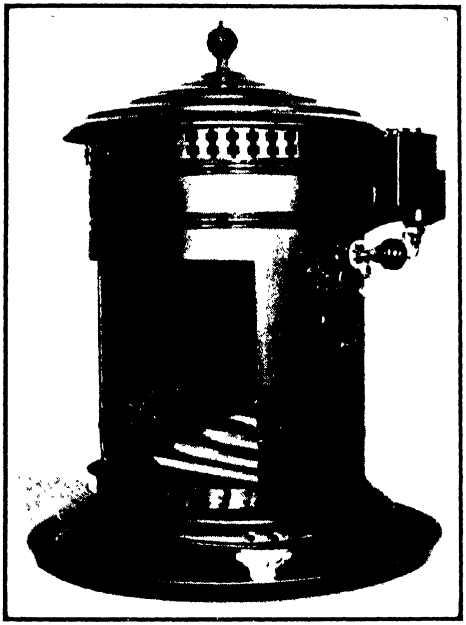

FIG. 85.—ALCOHOL HEATER WITH REFLECTOR.

III.—HEATING APPLIANCES.

As has already been explained, the alcohol flame itself radiates very little heat; nearly all of the latter goes upward with the products of combustion. When it is desired to heat a room with an alcohol stove, therefore, the intense heat of the alcohol flame is usually reflected out into the room by means of a curved sheet of copper, as shown in Fig. 85, or from a piece of non-combustible material like asbestos, which the flame renders red-hot. Or, as shown in Fig. 86, the gases circulate around metal jackets before leaving the stove, and the hot jackets then radiate the heat into the room. These heaters have been developed especially in Germany, where they are now quite generally used. They are useful wherever the hot air, hot water, or steam system of heating by coal is not available; it is to be recommended, however, when used in a closed room for any length of time, that the escaping products of combustion be led into a chimney by a specially-constructed flue, in order to avoid excessive vitiation of the atmosphere. This is at all times to be avoided as far as possible, but it occurs, of course, to a less extent with alcohol heaters than with either kerosene or gasolene burners, as has been explained.

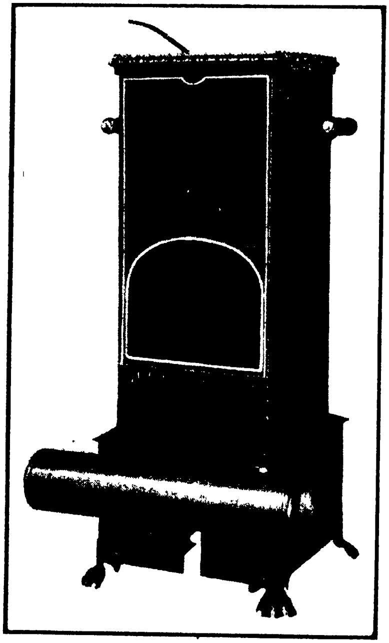

FIG. 86.—ANOTHER FORM OF ALCOHOL STOVE.

Grain alcohol has long been used for this purpose abroad. In this country, because of its greater cheapness, methyl or wood alcohol has been used to an extent which is hardly realized. This will be displaced by denatured grain alcohol very soon, as it is cheaper, and in many respects far superior.

One of the most widely used alcohol burning utensils in this country, doubtless has been the chafing dish, a form

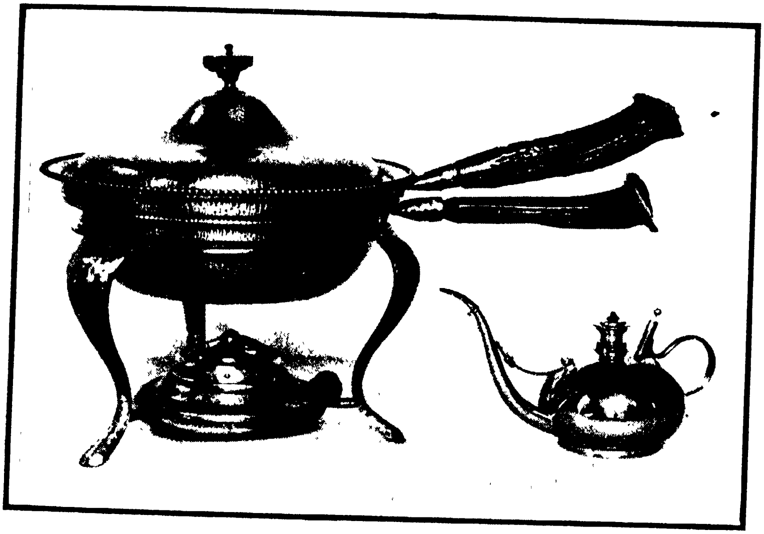

FIG. 87—ALCOHOL BURNING CHAFING DISH

of which, together with a small safety reservoir-can for holding the supply of spirit, is shown in Fig. 87. The chafing dish consists of a pan (attached to the lower handle) which ordinarily contains a little water. This lower pan is heated directly by the flame from the adjustable burner seen beneath, and serves as a heating jacket for the upper pan which rests in it, and in which the articles to be cooked are placed. A lid with a handle completes the apparatus. This utensil is capable of a great variety of uses. Its operation is rapid, and the heat is readily controlled; entire meals are frequently prepared on this simple apparatus. A prominent manufacturer estimates that perhaps two hundred and fifty thousand are in use in this country, and there will be a rapid increase in their employment when the convenience and economy of the utensil are more generally understood.

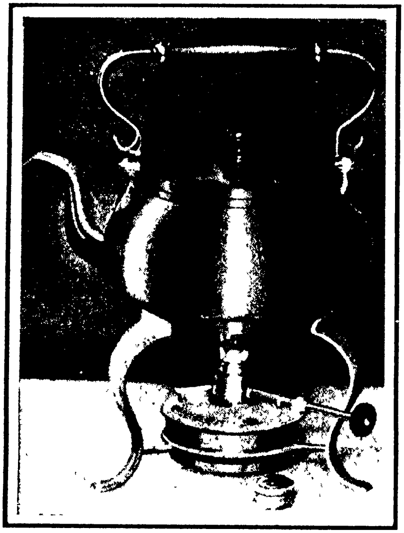
FIG. 88.—SPIRIT LAMP TEA KETTLE.

Perhaps better known and of more extended use are the spirit lamp tea-kettle and coffee percolator, illustrated in Figs. 88 and 89. The infusions of tea and coffee so obtained are not surpassed in flavor by those obtained with any other utensil. The coffee percolator is simple in operation; the ground coffee is placed on a sieve situated just below the glass portion, and water is introduced into the lower vessel. The glass globe serves to condense any little steam that is formed, for the water does not boil. The water when sufficiently heated rises because of its expansion through the central metal tube, which extends from near the bottom of the water up into the glass globe. The hot water flowing from the top of the tube percolates over the coffee on the sieve, and runs back into the vessel from which it started. The main mass of the water does not boil, but circulates up and down and the infusion is thus made without impairing the delicate aroma and flavor, as is done when coffee is boiled. When sufficiently strong, the coffee is drawn off by means of the faucet at the side.

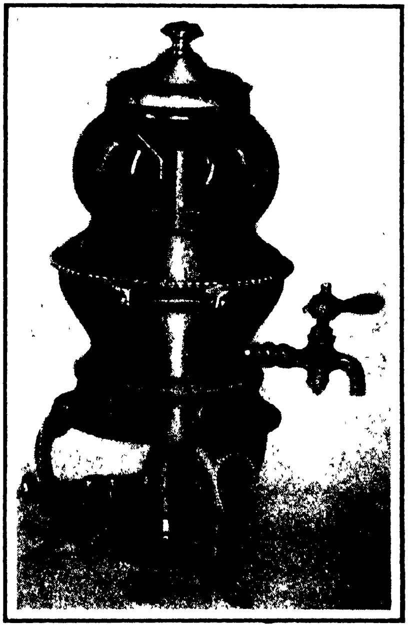

FIG. 89.—COFFEE PERCOLATOR HEATED WITH ALCOHOL.

The construction of the latest and most improved form of alcohol burner of the smaller type is shown in Fig. 90. The wick is made of cotton, which, however, is not seen here. The projecting part consists of a metal cap, which is filled with asbestos. This absorbs alcohol from the cotton wick in the reservoir below, and becoming heated, vaporizes the spirit. The flame issues from the various holes in the cap, and the height and intensity of the former are controlled by turning the wooden handle seen at the side. The asbestos becomes hard and non-absorbent after a while, but is easily replaced. There is, of course, a great variety of other burners in use, for example, the plain open dish with a support to hold vessels in, which is shown burning Smaragdin on page 376, a

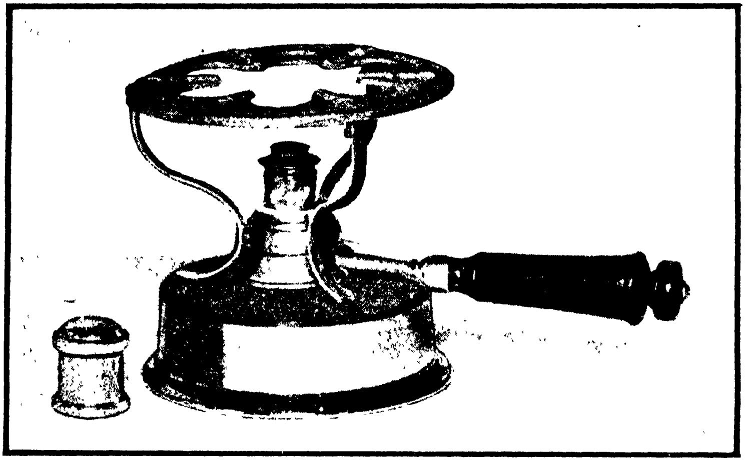

FIG. 90.—AN EFFICIENT ALCOHOL BURNER.

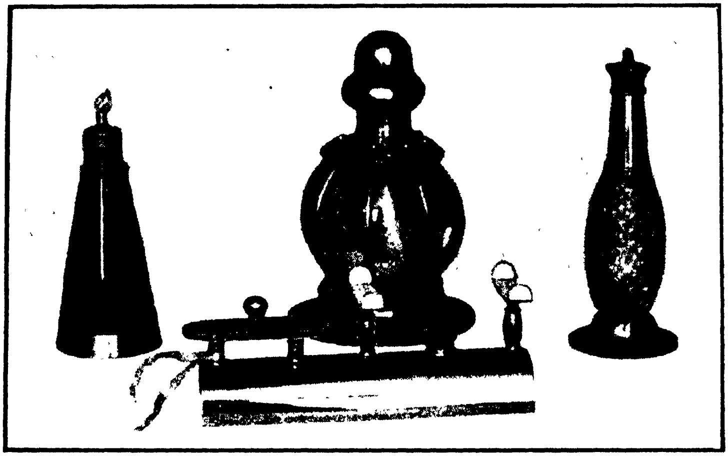

FIG. 91.—VARIOUS FORMS OF BURNERS.

similar dish filled with asbestos and covered with wire gauze, and the more improved kinds with various diaphragms and provided with means for altering the same, and thereby controlling the size of the flame. In Fig. 91 are illustrated various shapes of simple wick burners, which are used for cigar lighters, toilet purposes, etc., and a specially-constructed burner with rests for heating curling irons for the hair.

For travelers, picnickers, etc., the utensil shown in Fig. 92 is very handy; the lamp and support for the pot can be placed within the same, so that the whole is very compact. Some of these devices have a support for three eggs, which can be boiled in the coffee while it is being made, so that a light breakfast can be prepared with the one burner. There is also a gauze arrangement for toasting bread, which can be placed on a small stove like this.

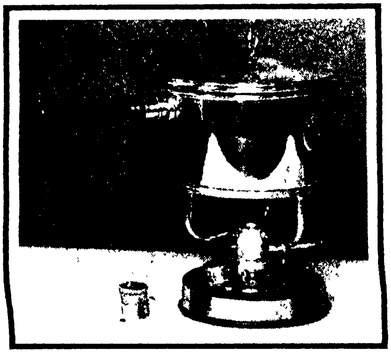

FIG. 92.—SIMPLE SPIRIT COOKER

Of larger stoves there are many varieties which have found extensive use, especially in Germany. Fig. 93 is an illustration of one of German manufacture, which gives a very strong flame and will do any work for which a gas or even coal stove is used. Fig. 94 shows a German stove with two burners; they are made with three and even four burners, so that any meal can be readily prepared with the one stove. Each of these burners will boil one quart of water in six to seven minutes, one gallon in twenty to twenty-five minutes. Each burner uses one-quarter to one-third quart of alcohol per hour for the hottest flame, which, with alcohol at 25 cents per gallon, will make each cost only two to three cents per hour. A gallon of water can be kept boiling for one hour, however, with one-tenth of a quart of spirit at a cost, therefore, of less than one cent.

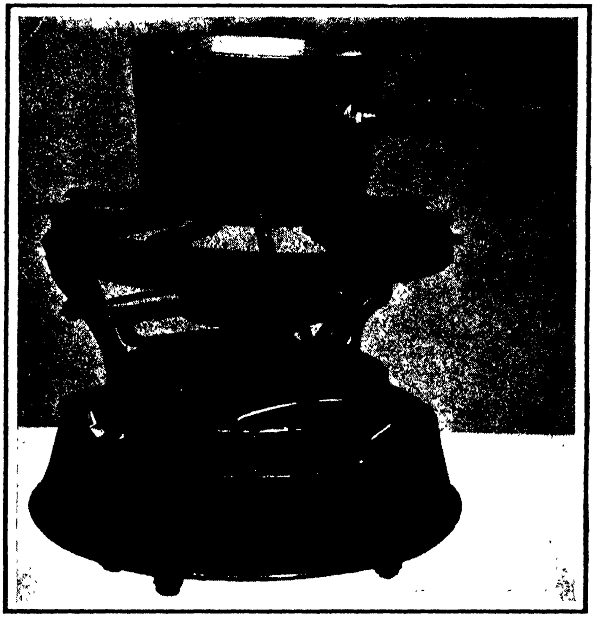

FIG. 93.—A SMALL ALCOHOL COOK STOVE.

An extremely handy utensil and one which is extensively used in Germany is the flat-iron shown in Fig. 95. These come in all sizes and weights up to twenty-five pounds and cost $2 to $5. The heating is done by a tube-like burner, which projects into the iron, and which is first started outside on a special stand, as is shown in Fig. 96. The iron becomes hot in ten minutes at the most, and remains at a constant temperature as long as the reservoir at the end is kept full. It holds about one-tenth quart, which lasts one hour on an average, and costs for this length of time less than one cent. There is no danger attending their use; and they do not require careful handling. The advantages of these irons, especially for warm weather, are obvious, and it may be predicted that their use here will soon be extensive.

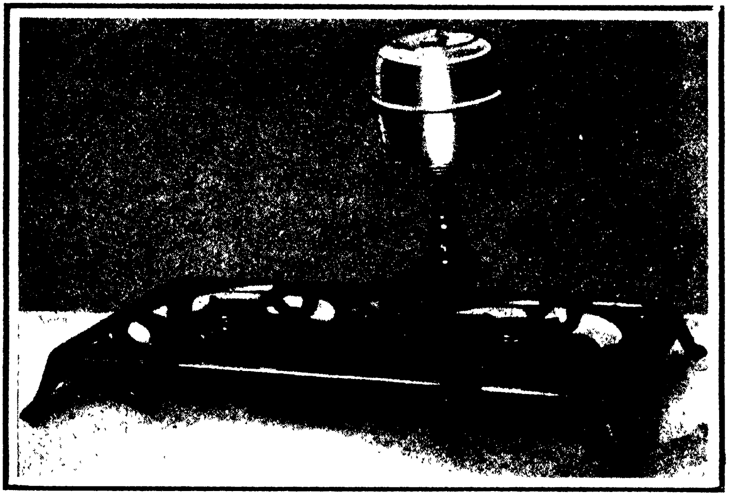

FIG 94.—TWO-BURNER ALCOHOL STOVE.

Another household utensil which is popular in Germany but is new here, is the water heater illustrated in Fig. 97. The water is continuously admitted from the

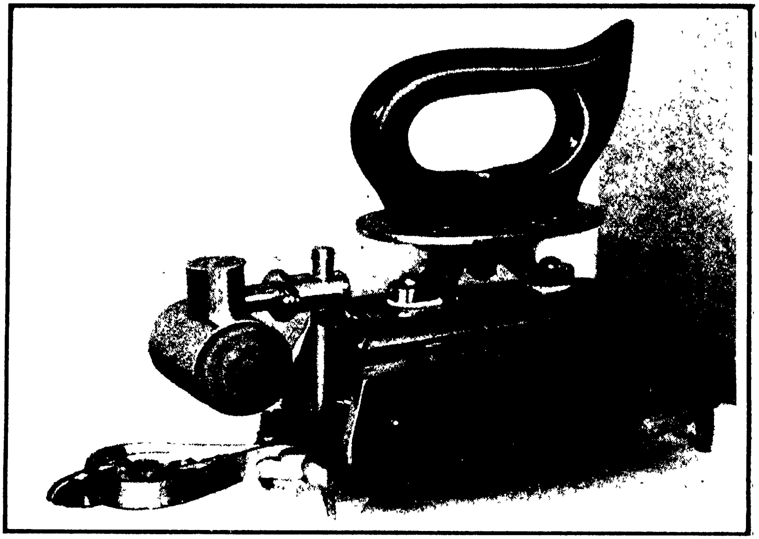

FIG. 95.—AN ALCOHOL HEATED FLAT IRON.

supply pipe through the faucet seen just back of the thermometer at the side. The burner is started as usual, and in fifteen seconds or so hot water flows either from the shower—the tube of which is here detached—or from the lower tube; the thermometer shows the temperature which is regulated by the rapidity of the flow of water. There is considerable escaping heat from the apparatus, which heats a small bath room quickly. One quart of alcohol, costing less than ten cents, will heat

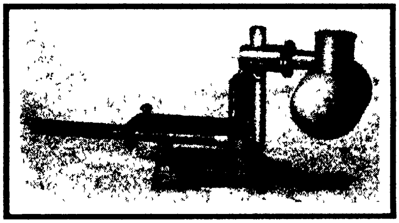

FIG. 96.—BURNER FOR THE ALCOHOL FLAT IRON.

forty gallons of water to a temperature of about 90° F. in ten to fifteen minutes, depending on the initial temperature of the water. This apparatus is 20 inches wide, 7 inches deep, and about 20 inches high, without the shower, which adds 40 inches. The whole can be fastened to the wall on

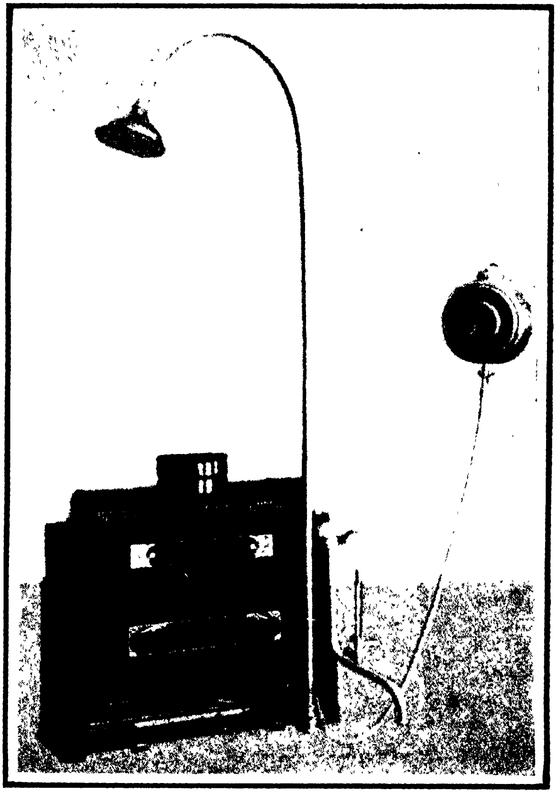

FIG. 97.—ALCOHOL WATER HEATER.

brackets. Its cost is about $35 in Germany. Doubtless it can be made and sold much cheaper here. It is an excellent arrangement where an immediate supply of hot water is desired. It will deliver water nearly at the boiling point in one-third of a minute. Of course, primarily, it is intended for the bath.

Still another apparatus is that shown in Fig. 98, which is used for the hot air drying of the hair, towels, hand-

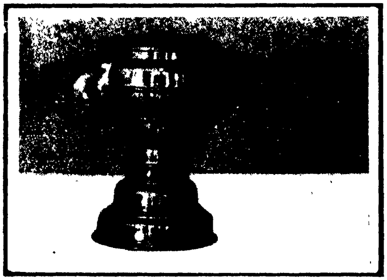

FIG. 98.—SPIRIT BURNING HAIR-DRYER.

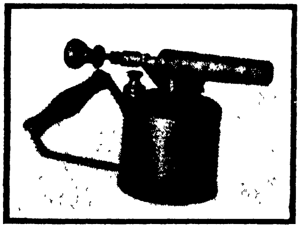

FIG. 100.—SOLDERING-IRON BLAST LAMP USING SPIRIT.

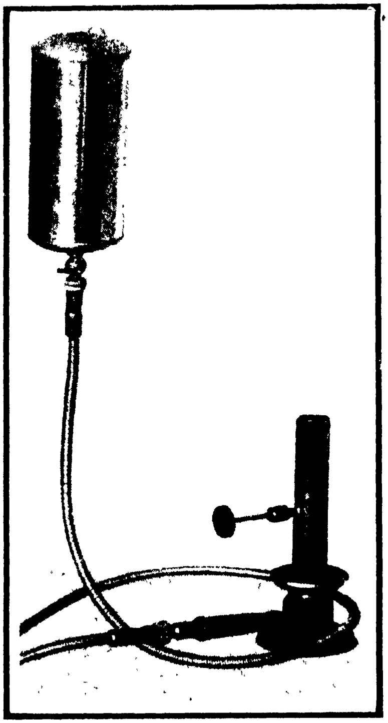

FIG. 99.—ALCOHOL BUNSEN BURNER.

kerchiefs, etc. A small spirit lamp at the base heats the air, which is forced through the apparatus and out of the spout by means of a revolving fan. The apparatus is very light, and can be held in one hand and operated with the thumb. It costs about $3.

A burner much used for heating utensils in chemical laboratories and in scientific work, is the Bunsen burner,

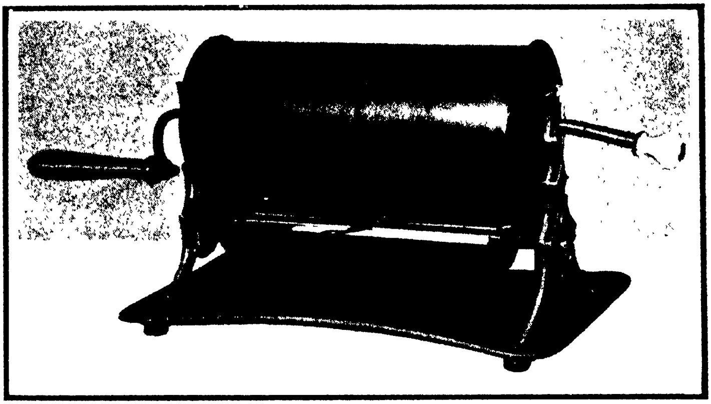

FIG. 101.—ALCOHOL COFFEE ROASTER.

shown in Fig. 99. Alcohol may be used where gas, which is cheaper and more convenient, is not obtainable. To start it a little alcohol is poured around the lower part and, being ignited, it heats that portion of the lamp so that the alcohol from the reservoir vaporizes when it reaches that point. After this the lamp itself furnishes sufficient heat to continue the vaporization. The rush of vapor sucks in air through a small hole seen near the cock of the burner, and the mixture burns at the top in a long intensely hot flame. This burner is very efficient in bringing articles to a high temperature. The soldering-iron blast lamp, shown in Fig. 100, is similar in construction and operation. The reservoir, however, is attached immediately and rigidly to the burner, which is provided with numerous holes for admitting air, and is operated with the thumb. It costs about $3. Another utensil which is used to some extent in Germany, although it probably will find little use here, is the coffee roaster, illustrated in Fig. 101.

These articles indicate the great variety of ways in which alcohol may be employed in domestic life, and this utilization will doubtless be greatly increased in the future by American inventors.

PART XVII.

ILLUMINATION WITH ALCOHOL.

IT is well known that the alcohol flame is practically colorless and non-luminous. Against a strong light it can scarcely be seen; it has not a bit of the characteristic bright, yellow radiancy of the gasolene, kerosene or gas flame, due, as has been shown in previous discussions, to the presence of almost white-hot incandescent or glowing particles of solid carbon.

Alcohol, nevertheless, can furnish most efficient and satisfactory illumination. For this purpose the intense heat of the alcohol flame is employed to bring to a white heat a so-called Welsbach mantle, a gauze-like hood which incloses the flame. It is composed of combinations of the rare chemical elements cerium, thorium, erbium, yttrium and zirconium. This form of light was first invented by the Austrian chemist, Auer von Welsbach. The mantle emits a soft, intensely white light when strongly heated, without undergoing any permanent chemical or physical change. These mantles are now widely used with gas in this country, as abroad, on a specially constructed burner, and it is a well-known and demonstrated fact that the cost of gas consumption for equal lighting effect is much less than with the naked self-luminous gas flame.

In order to secure the most intense heat and therefore the greatest illuminating power, as well as for other reasons, the gas is burnt in the Welsbach light in what is known as the Bunsen burner, the invention of the celebrated German chemist, Bunsen. In its simplest form it is much like the alcohol Bunsen burner shown in Fig. 99, that is, a slender, vertical tube with several small lateral holes. Immediately between these holes the gas or vapor rushes upward in a very fine jet and draws through them a quantity of air. The air and gas mix thoroughly in their course up the tube and burn at the top in a non-luminous, intensely hot flame.

Now alcohol can be utilized in this form of burner, as has been explained on page 388. It is vaporized at the base by the heat of the metal burner, mixes with air and

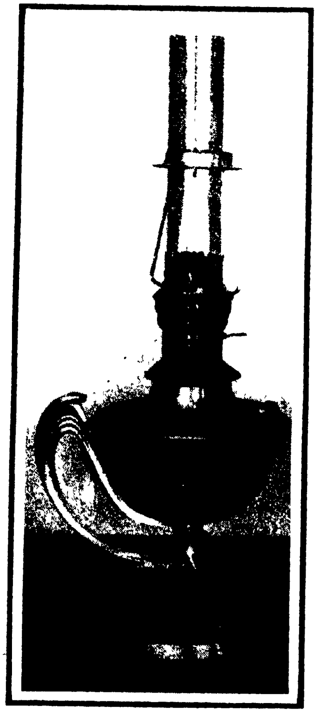

FIG. 102.—ORDINARY TYPE OF ALCOHOL LAMP

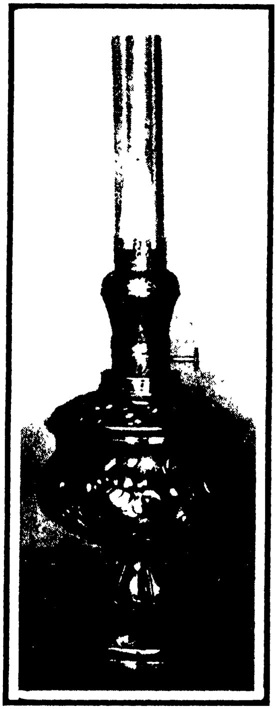

FIG. 103.—ALCOHOL LAMP WITH WELSBACH MANTLE.

burns at the top within the mantle, producing the well-known Welsbach light. In substance, therefore, the Welsbach gas-light and alcohol light are the same. The only difference is in the addition of a suitable arrangement at the base to vaporize the alcohol.

I.—THE ALCOHOL LAMP.

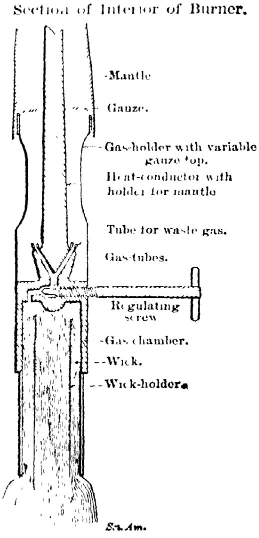
Section of Interior of Burner.
-Mantle
Gauze.
Gas-holder with variable gauze top.
Heat-conductor with holder for mantle
Tube for waste gas.
Gas-tubes.
Regulating screw
-Gas chamber.
--Wick.
--Wick-holder.
Sci. Am.

FIG. 104.—ALCOHOL LAMP BURNER.

The vaporizing section of the alcohol lamp does not differ much in external appearance or size from the ordinary kerosene lamp. Complete lamps of several varieties are shown in Figs. 102 and 103. The base of an ordinary oil lamp may be used without change, an additional mantle holder and vaporizing part for the alcohol being all that need be purchased new. This fact will doubtless aid greatly in the introduction of the alcohol lamp. The lamp is started by the ignition of a little alcohol at the base, obtained either by pumping up a few drops by pressing the little handle seen projecting from the base of the burner in Fig: 102, or by the addition of a few drops from a can through the oblong opening seen just beneath the chimney in Fig. 103. A lighted match is applied here, the alcohol takes fire and quickly heats the base, and on opening the gas valve by a few turns of the screw regulator seen at the side of Fig. 103, the flame leaps up to the mantle and the light is ready for use. It can be easily adjusted by the screw regulator, and instantly extinguished by closing the same.

The construction of a burner of this type is shown in cross section in Fig. 104. The wick, which is composed of cotton, absorbs the alcohol, which, passing upward, is vaporized by the heat of the metal part marked "gas chamber." This remains constantly hot while the lamp

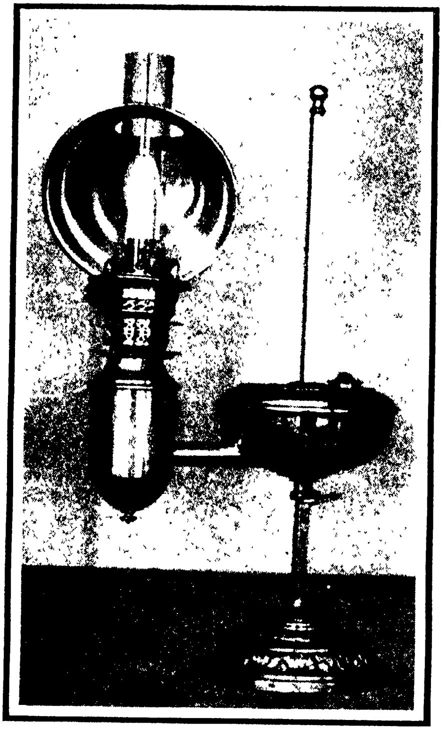

FIG. 105.—ALCOHOL STUDENT LAMP.

is burning, by the conduction of heat from the flame within the mantle through the metal "heat-conductor." The vapor mixes with air in the gas-holder and burns above the

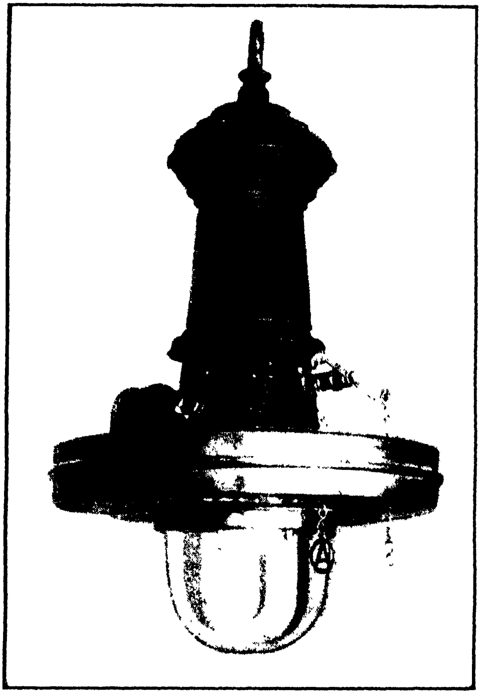

FIG. 106.—TWO HUNDRED CANDLE POWER SPIRIT LAMP.

gauze and within the mantle. The wick, of course, is not touched by the flame nor is it scorched; but nevertheless it should be replaced once every three months or so. These lamps average 50 candle power, so that they are equal to three incandescent burners.

In Fig. 105 is shown an alcohol lamp similar in construction to the others illustrated, excepting that it can be adjusted at various heights and is provided with a reflector. It is used by physicians, students, and others who desire a strong, concentrated light.

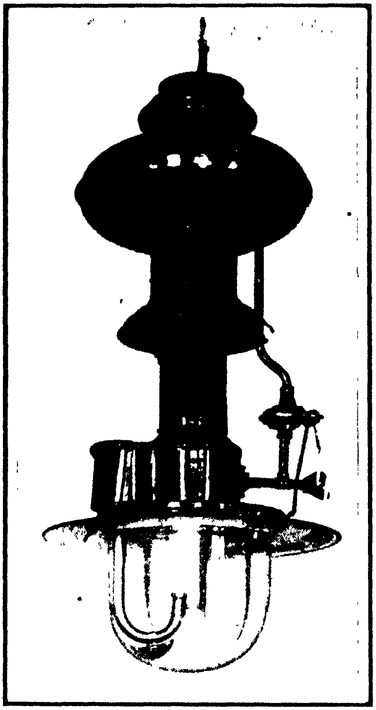

FIG. 107.—HIGH CANDLE POWER ALCOHOL LAMP.

For exterior lighting, lamps of a different construction are used. The mantle is beneath and the light is reflected downward; in many respects they much resemble the electric arc lamps in external appearance, as is seen in Figs. 106 and 107, which show lamps of German manufacture. The alcohol container and the vaporizing apparatus are in the upper part of the lamp, and the latter is heated by the ascending hot gases from the flame. The method of starting the lamp and its regulation are much the same as in the smaller portable ones just described. They are used extensively in Germany, where they cost on an average about $15 apiece. A 200-candle-power lamp consumes ½ pint of alcohol per hour, costing therefore about 1½ cents for each hour's lighting.

II.—ADVANTAGES OF THE ALCOHOL LAMP.

There are many places and occasions which require a portable hand lamp, and these are much used even in cities and towns where gas and electricity can be had cheaply, as is well known. For such purposes it may be confidently asserted that no lamp is as satisfactory as the alcohol incandescent lamp. Those of 25 candle-power produce only 86 grammes of carbonic acid gas per hour, whereas a kerosene lamp of the same power produces 234 grammes of this gas. The fouling of the atmosphere of a room lighted by alcohol is, therefore, less than half that caused by petroleum lamps. Furthermore, alcohol lamps are perfectly safe, and can be carried about from place to place. They do not make the hands greasy or oily, as do kerosene lamps. They require very little attention, there being no wicks to trim. The light is uniform and the lamp never smokes.

As regards the initial cost, the price of the alcohol lamp is about the same as that of the kerosene lamp now in use. The cost of operating the two is about equal also, for one-half gallon of alcohol will furnish as much light as one gallon of kerosene, which costs about half as much as alcohol. This is seen by the following comparative tests made by the Electrical Testing Laboratories of New York City, of a round wick center-draft kerosene lamp and an incandescent mantle alcohol lamp:

Lamp.	One gallon will last.	Candle power	Candle-power hours.
Alcohol	57 hrs. 5 min.	30.35	1732
Oil	28 hrs. 40 min.	30.8	883

In the following table the cost of alcohol light as compared with the other ordinary methods of illumination is given as reported by one German manufacturer who has made careful tests. The alcohol is taken as costing 30 cents per gallon:

(In cents per 16-candle power hour)	
Cost of alcohol used in lamps....	0.0008
Cost of gas.	0006
Cost of electricity.....	.0014
Cost of kerosene...........	.0010

This is at 18 cents per gallon for kerosene in Germany.

These are the figures for small lamps of the candle-power of the electric incandescent lamp. The amount of alcohol used per candle-power hour is much less for larger lights. Speaking generally, the cost of lighting by alcohol as compared with kerosene is in the ratio of 6 to 10 in favor of the alcohol. It will be noticed that gas only can compete with alcohol as an illuminant, while alcohol has the advantage of furnishing a portable light, which gas does not.

For certain purposes, therefore, alcohol possesses preeminent advantages as an illuminant, and there is every reason to expect that it will find extensive use in this country as it has abroad.

PART XVIII.

STATISTICS OF ALCOHOL PRODUCTION.

IT is undoubtedly of interest to know the progress and extent of the alcohol industry in this and other countries. The statistics of the manufacture, uses, and price of the various varieties of alcohol, here and abroad, follow, and from these some idea of the possible extension of the industry and the probable cost of alcohol in our country can be obtained.

I.—UNITED STATES.

The following statistical data are from the reports of the Commissioner of Internal Revenue, for the fiscal year ended June 30, 1905:

TABLE I.—DISTILLERIES REGISTERED AND OPERATED DURING THE YEAR ENDED JUNE 30, 1905.

	Grain.		Molasses.		Fruit.		Total Registered.	Total Operated.
	Registered.	Operated.	Registered.	Operated.	Registered.	Operated.		
Total.	896	728	14	13	1,108	1,031	2,018	1,772

TABLE II.—QUANTITIES OF GRAIN AND OTHER MATERIALS USED FOR THE PRODUCTION OF DISTILLED SPIRITS DURING THE FISCAL YEAR ENDED JUNE 30, 1905.

	Bushels.
Malt	3,798,578
Wheat	12,481
Barley	9,874
Rye	5,489,028
Corn	20,592,504
Oats	18,898
Mill feed	1,462
Other materials	4,500
Total	29,927,325
Molasses	20,549,553 Gals.

TABLE III.—COMPARATIVE STATEMENT OF MATERIALS USED AND SPIRITS PRODUCED DURING THE LAST TWO FISCAL YEARS.

Year.	Grain Used.	Spirits Produced from Grain	Molasses Used to Produce Spirits.	Spirits Produced from Molasses	Molasses Used to Produce Rum	Rum Produced	Total Production
	Bushels.	Gallons.	Gallons	Gallons	Gallons.	Gallons.	Gallons.
1904 ..	27,687,683	123,519,427	16,425,853	8,961,316	2,123 553	1,801,179	134,311,952
1905. ..	29,927,325	133,932,478	18,387,650	12,086,329	2,161 903	1,791 987	147,810,794

The average yield per bushel of grain was $\frac{133,932,478}{29,927,325} = 4.47 +$ gallons of spirits.

The average yield per gallon of molasses used for the production of spirits was $\frac{12,086,329}{18,387,650} = 0.657 +$ gallon.

The average yield per gallon of molasses used for the production of rum was $\frac{1,791,987}{2,161,903} = 0.828 +$ gallon.

II.—GERMANY.

The following statistics have been compiled by the Bureau of Statistics of the United States Department of Agriculture, from the Vierteljahrshefte zur Statistik des Deutschen Reichs, 1906:

TABLE IV.—PRODUCTION OF SPIRITS IN GERMANY DURING THE INDUSTRIAL YEARS (OCTOBER 1 TO SEPTEMBER 30) 1904-5 AND 1903-4.

Distilleries.	1887-1888.	1903-1904.		1904-1905	
	Alcohol Produced.	Distilleries in Operation.	Alcohol Produced.	Distilleries in Operation.	Alcohol Produced.
Agricultural distilleries:			Gallons.		Gallons
Potato	....	6,059	80,304,589	6,048	75,860,933
Grain	....	8,934	7,593,514	7,620	8,615 719
Total........	......	14,993	87,898 103	13,668	84,476,652
Industrial distilleries:					
Potato....	......	22	151,158	21	149,864
Grain	......	788	10,699,810	780	11,612,490
Molasses .	....	29	2,452,501	29	2,851,715
Other materials...	......	39	2,695	39	4,253
Total.....	....	878	13 306,164	869	14 618 322
Other distilleries working up non-farinaceous materials..	.....	50,160	614,750	57,635	958 145
Grand total.....	80,783,846	66,031	101,819,017	72,172	100,053,119

TABLE V.—MATERIALS WORKED UP IN DISTILLERIES IN GERMANY DURING THE INDUSTRIAL YEARS (OCTOBER 1 TO SEPTEMBER 30) 1903–4 AND 1904–5.

Materials.	1903 1904.	1904-1905.
	Tons	Tons.
Potatoes	2,900,461	2,734,443
Rye	119,510	126,416
Barley	184,323	186,359
Corn and dari	93,319	121.350
All other grains and farinaceous materials	21,556	22,728
Molasses, beets and beet juice	40,027	45,497
Other materials	1,143	1,182
Totals	3,360 339	3,237,975
	Gallons.	Gallons.
Brewery refuse and yeast broth	2,273,471	2,123,742
Seed fruit and pomace	2,317,880	7,167,540
Stone fruit	5,049,372	10,359,400
Fruit and grape wine	554,651	871,497
Wine lees and rapes	14,109,293	16,359,414
Other materials	2,274,847	3,004,881
Totals	26,579,517	39,886,474

TABLE VI.—CONSUMPTION OF TAX-FREE ALCOHOL IN THE GERMAN EMPIRE.

Industrial Year. October 1 to September 30.	Total Tax-Free Alcohol	Fully Denatured			Partially Denatured.
		By the Usual Method.	By the Admixture of Benzene.	Total.	
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1904	36,943,805	24,418,052	1,471,004	25,889,056	10,353,615
1903	36,769 690	24,604,952	1,393,867	25,998,819	10,195,535
1902	33,779,735	23,002,206	778,113	23,780 319	9,529,405
1901	29,324,191	......	......	18,616,826	9,137,482
1900	30,534,591	......	......	20,665,887	8,975,281
1895	19,000,000	......	......	11,000,000	7,000,000
1888	10 250,000	......	......	3,600,000	6,100,000

(TABLE VI —CONTINUED)

Industrial Year, October 1 to September 30.	Without Denaturation.				
	In Public Hospitals, etc.	In Public Scientific Institutions	In Military Technical Institutions.	For Making Smokeless Powder, Fuses and Fulminates	Total
	Gallons.	Gallons.	Gallons.	Gallons	Gallons.
1904 . . .	74,206	53,679	10,752	562,497	701,134
1903.	65,937	50,905	3,540	454,954	575,336
1902.	58,672	51,566	15,903	343,870	470,011
1901.	53,125	51,619	. . . .	458,995	*1,569,883
1900.	48,634	46,890	. . . .	457,569	†893,423
1895. . . .	. . . .	. . . .	. . . .	. . . .	1,000,000
1888. . .	. . . .	. . . .	. . . . .	. . . .	550,000

* Of which 1,006,144 gallons were used in the manufacture of medicine.
† Of which 340,330 gallons were used in the manufacture of medicine.

It must not be forgotten in comparing the figures for Germany with those of the United States, that the German alcohol is given in gallons of 95 per cent commercial strength, and that, therefore, in order to compare them with the taxable gallons of 50 per cent strength produced in the United States they must be almost doubled. During 1905 the total number of taxable gallons produced in the United States, other than from fruit, was 147,810,794, and from fruit, 5,448,584, a total of 153,259,378. The figures for Germany show, therefore, a total of 100,053,119 gallons, or about 200,000,000 United States taxable gallons. In round numbers, therefore, the German production for the past year is 50,000,000 taxable gallons greater than in the United States.

An idea of the total number of alcohol engines in operation in Germany may be obtained from those in use in the city of Berlin in 1903. One central station alone in that city had, at that time, contracts for supplying 1,011 alcohol engines. These were distributed among the various industries as follows:

TABLE VII.

Agricultural purposes	544
Pumping plants	88
Creameries	63
Electric light plants	52
Woodworking machinery	45
Flour mills	40
Bakeries	33
Motor trucks	30
Boats	30

The rest were used for general power purposes.

As regards the prices of the various substances used in Germany for denaturing alcohol they are, depending upon the quantity ordered, as follows:

TABLE VIII.

	Prices in cents, per lb.
4 parts wood alcohol, 1 part pyridin base	9.75 to 10.90
Denatured wood alcohol	8.65 to 10.80
Pyridin bases	13.50 to 15.15
Camphor	55.17 to 57.40
Turpentine oil	17.30 to 24.30
Benzene	8.65 to 10.80
Sulphuric ether	24.30 to 30.30
Animal oil	27.00 to 32.50
Chloroform	16.80 to 19.50
Iodoform	292.00 to 325.00
Ethyl bromide	54.00 to 70.40
Benzine	7.50 to 8.10
Technically pure methyl alcohol	10.80 to 13.00
Castor oil	18.90 to 21.20
Lye	5.00 to 6.40

The retail selling price of alcohol varies greatly from year to year in Germany, as is seen in the following table, which gives the prices of 90 per cent alcohol for the last four years:

TABLE IX.

1903.	1904.	1905.	1906.
13½c.	30c.	18c.	29c.

The high prices of the years 1904 and 1906 were caused by the poor potato crop resulting from abnormally dry seasons.

III.—FRANCE.

The consumption of denatured alcohol in France for the years 1903 to 1905, inclusive, is shown in the following table, which is taken from Sidersky, Bull. de l'Association Des Chimistes de Sucerie et de Distillerie, November, 1905, p. 545; 1905 figures are from Zeitschrift der Spiritus-industrie, 1906, 29, No. 35,323:

TABLE X.—CONSUMPTION OF DENATURED ALCOHOL IN FRANCE, 1903-1905, INCLUSIVE.

Purpose for Which Used.	1903. Gallons.	1904. Gallons.	1905. Gallons.
Heating and lighting........	6,922,218	7,654,287	8,326,084
Varnishes	305,909	328,443	305,222
Polishes, etc................	66,095	47,552	46,415
Plastic materials.............	530,851	495,874	562,497
Manufacture of hats..........	9,642	6,287	6,023
Dyeing and colors.............	14,054	10,329	14,635
Rennet	3,751	2,932	3,910
Collodion	3,857	7,185	11,016
Chloroform	9,959	4,596	4,914
Choral	6,499	7,978	10,091
Tanning materials............	21,081	40,920	14,978
Chemical and pharmaceutical products	300,652	182,410	178,843
Scientific uses................	13,710	22,824	31,515
Ethers, fulminates, explosives.	1,687,495	2,375,342	2,961,900
Total	9,895,773	11,186,959	12,478,043

The cost of denaturing in France is quite heavy, as is shown by the following table giving the amounts and costs of the denaturants, which must be added to each hectoliter (100 liters equal to 26.42 gallons):

TABLE XI.

	Francs.
15 liters of methyline (wood alcohol)..................	19.50
½ liter heavy benzine................................	.30
1 gram malachite green...............................	.06
Total cost of denaturants for 26.42 gallons..........	19.86
Equal to..	$3.70

A fair average price for the market value of crude alcohol in France is $5.21 per hectoliter, or 20 cents per gallon. The price, of course, fluctuates somewhat in France, as it does elsewhere. When we add to this price the cost of denaturing, as given above, we have a total cost of $8.91 for 115½ liters—about 30 gallons of denatured alcohol. The net cost per gallon of industrial alcohol in France, in ordinary times, is, therefore, about 30 cents.

IV.—GREAT BRITAIN.

The following table is taken from the Report of the English Industrial Alcohol Committee, 1905, and shows the quantity of denatured alcohol produced in Great Britain during the years 1900 to 1904:

TABLE XII.

Year.	Ordinary methylated spirit.	Mineralized methylated spirit.	Total.
1900	2,058,450	1,328,162	3,386,612
1901	2,075,514	1,439,243	3,514,757
1902	2,157,127	1,410,603	3,567,730
1903	2,213,580	1,464,672	3,678,252
1904	[a]2,139,784	1,527,573	3,667,357

[a] Decrease mainly due to the fact that certain firms were allowed to denature alcohol by other substances than wood naphtha.

Until within the last few years the British alcohol supply has been drawn largely from Germany, but the importation of German plain alcohol to be denatured for industrial purposes has now almost entirely vanished. The prices have been governed mainly by the quantity of potatoes available in eastern Europe for conversion into alcohol. They show, therefore, the same wide variations as Germany, and are for the last five years of importing: 18.6, 13.8, 17.2, 28.5, and 36.83 cents per gallon.

V.—BELGIUM.

The tax on denatured alcohol to be used for industrial purposes was removed in 1896 by the Belgium government. The increase in the use of alcohol for such purposes has been rapid since 1896, as is seen in the following table:

TABLE XIII.

	Gallons.
1896	126,658
1897	284,211
1898	290,316
1899	286,711
1900	425,178
1901	575,447
1902	924,421

There was used, therefore, in Belgium, seven times as much denatured alcohol in 1902 as in 1896.

DIRECTOR OF INDUSTRIES
Bengal

APPENDIX.

APPENDIX.

CIRCULAR NO. 680.

SPECIFICATIONS FOR METHYL ALCOHOL AND BENZINE, SUBMITTED FOR APPROVAL AS DENATURING MATERIALS.

Treasury Department,
Office of the
Commissioner of Internal Revenue,
Washington, October 30, 1906.

The second paragraph of section 1 of the act approved June 7, 1906, for the withdrawal from bond, tax free, of domestic alcohol to be rendered unfit for beverage or liquid medicinal purposes by the admixture of denaturing materials, provides as follows:

> The character and quantity of the said denaturing material and the conditions upon which said alcohol may be withdrawn free of tax shall be prescribed by the Commissioner of Internal Revenue, who shall, with the approval of the Secretary of the Treasury, make all necessary regulations for carrying into effect the provisions of this Act.

Pursuant to this authority, and in conformity with the terms of section 26 of regulations No. 30, the following specifications are prescribed for methyl alcohol and benzine submitted for approval as denaturing materials.

METHYL ALCOHOL.

The methyl alcohol submitted must be partially purified wood alcohol obtained by the destructive distillation of wood. It must conform to the following analytical requirements:

Color.—This shall not be darker than that produced by a freshly prepared solution of 2 c. c. of N/10 iodine diluted to 1,000 c. c. with distilled water.

Specific gravity.—It must have a specific gravity of not more than 0.830 at 60° F. (15.56° C.), corresponding to 91° of Tralles' scale.

Boiling point.—One hundred c. c. slowly heated in a flask under conditions as described below must give a distillate of not less than 90 c. c. at a temperature not exceeding 75° C. at the normal pressure of the barometer (760 mm.).

One hundred c. c. of wood spirit are run into a short-necked copper flask of about 180-200 c. c. capacity, and the flask placed on an asbestus plate having a circular opening of 30 mm. diameter. In the neck of this flask is fitted a fractionating tube 12 mm. wide and 170 mm. long, with a bulb just 1 centimeter below the side tube, which is connected with a Liebig's condenser having a water jacket not less than 400 mm. long. In the upper opening of the fractionating tube is placed a standardized thermometer, so adjusted that its mercury bulb comes in the center of the bulb. The distillation is conducted in such a manner that 5 c. c. pass over in one minute. The distillate is run into a graduated cylinder, and when the temperature of 75° C. has been reached at the normal barometric pressure of 760 mm. at least 90 c. c. shall have been collected.

Should the barometer vary from 760 mm. during the distillation, 1° C. shall be allowed for every variation of 30 mm. For example, at 770 mm. 90 c. c. should have distilled at 75.3°. and at 750 mm. 90 c. c. should have distilled at 74.7° C.

Miscibility with water.—It must give a clear or only slightly opalescent solution when mixed with twice its volume of water.

Acetone content.—It must contain not more than 25 or less than 15 grammes per 100 c. c. of acetone and other substances estimated as acetone when tested by the following method (Messinger):

Determination of acetone.—1 c. c. of a mixture of 10 c. c. wood naphtha with 90 c. c. of water is treated with 10 c. c. of double normal soda solution. Then 50 c. c. of N/10 iodine solution are added while shaking, and the mixture made acid with dilute sulphuric acid three minutes after the addition of the iodine. The excess of iodine is titrated back with N/10 sodium thiosulphate solution, using a few drops of starch solution for an indicator. From 15.5 to 25.8 c. c. of N/10 iodine solution should be used by the spirit.

The solution should be kept at a temperature between 15° and 20° C.

Calculation: X = grammes of acetone in 100 c. c. of spirit.
Y = number of c. c. of N/10 iodine solution required.
N = volume of spirit taken for titration.

$$\text{Then } X = \frac{Y \times 0.096672}{N}$$

Esters.—It should contain not more than 5 grammes of esters per 100 c. c. of spirit, calculated as methyl acetate and determined as follows:

Five c. c. of wood spirit are run into a flask, and 10 c. c. normal sodium hydroxide free from carbonates are added, and the flask connected with a return condenser and boiled for two hours. Instead of digesting at boiling temperature the flasks may be allowed to stand over night at room temperature, and then heated on a steam bath for thirty minutes with an ordinary tube condenser. The liquid after digestion is cooled and titrated with normal sulphuric acid, using phenolphthalein as an indicator.

$$\text{Methyl acetate, grammes per 100 c. c. of spirit} = \frac{0.074 \times \text{c. c. of } N/\text{soda required} \times 100}{\text{c. c. spirit taken.}}$$

Bromine absorption.—It must contain a sufficient quantity of impurities derived from the wood, so that not more than 25 c. c. or less than 15 c. c. shall be required to decolorize a standard solution containing 0.5 gramme of bromine, as follows:

The standard bromine solution is made by dissolving 12.406 grammes of potassium bromide and 3.481 grammes of potassium bromate (which is of tested purity and has been dried for two hours at 100° C.) in a liter of water. Fifty c. c. of the standard solution containing 0.5 gramme of bromine are placed in a glass-stoppered flask having a capacity of about 200 c. c. This is acidified by the addition of 10 c. c. of diluted sulphuric acid (1 to 4), and the whole shaken and allowed to stand a few minutes. The wood alcohol is then allowed to flow slowly into the mixture, drop by drop, from a burette until the color is entirely discharged. The temperature of the mixture should be 20° C.

In addition to the above requirements the methyl alcohol must be of such a character as to render the ethyl alcohol with which it is mixed unfit for use as a beverage.

BENZINE.

The benzine submitted for approval must be a hydrocarbon product derived either from petroleum or coal tar. If derived from petroleum, it must have a specific gravity of not less than 0.800. If derived from coal tar, it must have a boiling point of not less than 150° or more than 200° C.

It must be of such character as to impart a decided odor to ethyl alcohol when mixed with it in the proportion of one-half of one part by volume.

JOHN W. YERKES,
Commissioner.

Approved:
C. H. KEEP,
Acting Secretary of the Treasury.

DIRECTOR OF INDUSTRIES
Bengal

REGULATIONS NO. 30.

UNITED STATES INTERNAL REVENUE.

REGULATIONS AND INSTRUCTIONS CONCERNING DENATURED ALCOHOL, UNDER THE ACT OF CONGRESS OF JUNE 7, 1906.

SEPTEMBER 29, 1906.

SEC. 1. The following regulations are issued pursuant to an act of the Congress providing for the withdrawal from bond, tax free, of domestic alcohol to be rendered unfit for beverage or liquid medicinal uses by the admixture of denaturing materials:

The act in question is as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after January first, nineteen hundred and seven, domestic alcohol of such degree of proof as may be prescribed by the Commissioner of Internal Revenue and approved by the Secretary of the Treasury, may be withdrawn from bond without the payment of internal-revenue tax, for use in the arts and industries, and for fuel, light, and power, provided said alcohol shall have been mixed in the presence and under the direction of an authorized Government officer, after withdrawal from the distillery warehouse, with methyl alcohol or other denaturing material or materials, or admixture of the same, suitable to the use for which the alcohol is withdrawn, but which destroys its character as a beverage and renders it unfit for liquid medicinal purposes; such denaturing to be done upon the application of any registered distillery in denaturing bonded warehouses specially designated or set apart for denaturing purposes only, and under conditions prescribed by the Commissioner of Internal Revenue with the approval of the Secretary of the Treasury.

The character and quantity of said denaturing material and the conditions upon which said alcohol may be withdrawn free of tax shall be prescribed by the Commissioner of Internal Revenue, who shall, with the approval of the Secretary of the Treasury, make all necessary regulations for carrying into effect the provisions of this Act.

Distillers, manufacturers, dealers, and all other persons furnishing, handling, or using alcohol withdrawn from bond under the provisions of this Act shall keep such books and records, execute such bonds, and render such returns as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may by regulation require. Such books and records shall be open at all times to the inspection of any internal-revenue officer or agent.

Sec. 2 That any person who withdraws alcohol free of tax under the provisions of this Act and regulations made in pursuance thereof, and who removes or conceals same, or is concerned in removing, depositing, or concealing same for the purpose of preventing the same from being denatured under governmental supervision, and any person who uses alcohol withdrawn from bond under the provisions of section one of this Act for manufacturing any beverage or liquid medicinal preparation, or knowingly sells any beverage or liquid medicinal preparation made in whole or in part from such alcohol, or knowingly violates any of the provisions of this Act, or who shall recover or attempt to recover by redistillation or by any other process or means, any alcohol rendered unfit for beverage or liquid medicinal purposes under the provisions of this Act, or who knowingly uses, sells, conceals, or otherwise disposes of alcohol so recovered or redistilled, shall on conviction of each offense be fined not more than five thousand dollars, or be imprisoned not more than five years, or both, and shall, in addition, forfeit to the United States all personal property used in connection with his business, together with the buildings and lots or parcels of ground constituting the premises on which said unlawful acts are performed or permitted to be performed: *Provided*, That manufacturers employing processes in which alcohol, used free of tax under the provisions of this act, is expressed or evaporated from the articles manufactured, shall be permitted to recover such alcohol and to have such alcohol restored to a condition suitable solely for reuse in manufacturing processes under such regulations as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, shall prescribe.

Sec. 3. That for the employment of such additional force of chemists, internal-revenue agents, inspectors, deputy collectors, clerks, laborers, and other assistants as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may deem proper and necessary to the prompt and efficient operation and enforcement of this law, and for the purchase of locks, seals, weighing beams, gauging instruments, and for all necessary expenses incident to the proper execution of this law, the sum of two hundred and fifty thousand dollars, or so much thereof as may be required, is hereby appropriated out of any money in the Treasury not otherwise appropriated, said appropriation to be immediately available.

For a period of two years from and after the passage of this act the force authorized by this section of this act shall be appointed by the Commissioner of Internal Revenue, with the approval of the Secretary of tne Treasury, and without compliance with the conditions prescribed by the act entitled "An act to regulate and improve the civil service," approved January sixteenth, eighteen hundred and eighty-three, and amendments thereof, and with such compensation as the Commissioner of Internal Revenue may fix, with the approval of the Secretary of the Treasury.

Sec. 4. That the Secretary of the Treasury shall make full report to Congress at its next session of all appointments made under the provisions of this act, and the compensation paid thereunder, and of all regulations prescribed under the provisions hereof, and shall further report what, if any, additional legislation is necessary, in his opinion, to fully safeguard the revenue and to secure a proper enforcement of this act.

Approved, June 7, 1906.

PART I.*

DENATURING BONDED WAREHOUSES.

Sec. 2. The proprietor of any registered distillery may withdraw from his distillery warehouse, free of tax, alcohol of not less than 180 degrees proof or strength, to be denatured in the manner hereinafter prescribed.

A distiller desiring to withdraw alcohol from bond for denaturing purposes under the provisions of this act shall, at his own expense, provide a denaturing bonded warehouse, to be situated on and constituting a part of the distillery premises. It shall be separated from the distillery and the distillery bonded warehouse and all other buildings, and no windows or doors or other openings shall be permitted in the walls of the denaturing bonded warehouse leading into the distillery, the distillery bonded warehouse or other room or building, except as hereinafter provided. It must be constructed in the same manner as distillery bonded warehouses are now constructed, with view to the safe and secure storage of the alcohol removed thereto for denaturing purposes and the denaturing agents to be stored therein. It must be approved by the Commissioner of Internal Revenue. It shall be provided with closed mixing tanks of sufficient capacity. The capacity in wine gallons of each tank must be ascertained and marked thereon in legible letters, and each tank must be supplied with a graduated glass gauge whereon the contents will be at all times correctly indicated. All openings must be so arranged that they can be securely locked. Suitable office accommodation for the officer on duty must be provided.

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* Persons desiring information as to distilleries will be supplied on request with the proper regulations.

Sec. 3. The denaturing bonded warehouse shall be used for denaturing alcohol, and for no other purpose, and nothing shall be stored or kept therein except the alcohol to be denatured, the materials used as denaturants, the denatured product, and the weighing and gauging instruments and other appliances necessary in the work of denaturing, measuring, and gauging the alcohol and denaturing materials.

These bonded warehouses must be numbered serially in each collection district, and the words "Denaturing bonded warehouse No. ——, district of ——," must be in plain letters in a conspicuous place on the outside of the building.

In case the distiller's bond has been executed before the erection of such warehouse the consent of the sureties to the establishment of the denaturing warehouse must be secured and entry duly signed made on the bond.

DENATURING MATERIAL ROOM.

Sec. 4. There shall be provided within the denaturing bonded warehouse a room to be designated as the denaturing material room. This room is to be used alone for the storage of denaturing materials prior to the denaturing process. It must be perfectly secure, and must be so constructed as to render it impossible for anyone to enter during the absence of the officer in charge without the same being detected.

The ceiling, inside walls, and floor of said room must be constructed of brick, stone, or tongue-and-groove planks. If there are windows in the room the same must be secured by gratings or iron bars, and to each window must be affixed solid shutters of wood or iron, constructed in such manner that they may be securely barred and fastened on the inside. The door must be substantial, and must be so constructed that it can be securely locked and fastened.

Sec. 5. At least two sets of tanks or receptacles for storing denaturing material must be provided, and each set of tanks must be of sufficient capacity in the aggregate to hold the denaturing material which it is estimated the distiller will use for thirty days. A set of tanks shall consist of one or more tanks for storing methyl alcohol, and one or more tanks of smaller capacity for storing other denaturing materials. The capacity of each tank must be ascertained and marked in legible figures on the outside.

The tanks must not be connected with each other, and must be so constructed as to leave at least 18 inches of open space between the top of the tank and ceiling, the bottom of the tank and the floor, and the sides of the tank and walls of the denaturing material room. Each tank shall be given a number, and this number must be marked upon it. There shall be no opening at the top except such as may be necessary for dumping the denaturing material into the tank and thoroughly plunging or mixing the same. Said opening must be covered so that it may be locked. Likewise the faucet through which the denaturing material is drawn must be so arranged that it can be locked. Each tank must be supplied with a graduated glass gauge whereby the contents of the tank will always be shown.

CUSTODY OF DENATURING BONDED WAREHOUSE.

Sec. 6. The denaturing bonded warehouse shall be under the control of the collector of the district and shall be in the joint custody of a storekeeper, storekeeper-gauger, or other designated official and the distiller.

No one shall be permitted to enter the warehouse except in the presence of said officer, and the warehouse and room shall be kept closed and the doors, exterior and interior, securely locked except when some work incidental to the process of denaturing or storing material is being carried on. Standard Sleight locks shall be used for locking the denaturing bonded warehouse and the denaturing material room, and they shall be sealed in the same manner and with the same kind of seals as distillery bonded warehouses and cistern rooms are now sealed. Miller locks shall be used in securing the faucets and openings of the mixing tanks and the denaturing material tanks.

The officer in charge of the denaturing bonded warehouse, material room, and tanks shall carry the keys to same, and under no circumstances are said keys to be intrusted to any one except another officer who is duly authorized to receive them.

APPLICATION FOR APPROVAL OF DENATURING BONDED WAREHOUSE.

Sec. 7. Whenever a distiller wishes to commence the business of denaturing alcohol he must make written application to the collector of the district in which the distillery is located for the approval of a denaturing bonded warehouse.

Such application must give the name or names of the person, firm, or corporation operating the distillery, the number of the distillery, the location of the same, the material of which the warehouse is constructed, the size of same, width, length, and height, the size of the denaturing material room therein, and the manner of its construction, the capacity in gallons of each tank to be used for denaturing alcohol or for holding the denaturing agents, and the material of which said tanks are constructed.

Such application must be accompanied by a diagram correctly representing the warehouse, the mixing tanks, denaturing material room, and denaturing material tanks, with all openings and surroundings. It must show the distillery and all the distillery bonded warehouses on the premises, with dimensions of each.

The application may be in the following form:

To collector of ——— district of ———.

Sir: The undersigned ——— ——— doing business under the name or style of ——— hereby makes application for the approval of a denaturing bonded warehouse which he has provided as required by law, situated upon and constituting a part of the premises known as Distillery No —— at ———, in the county of ———, and State of ———.

Said denaturing warehouse is constructed of

———————————————————————————————

———————————————————————————————

(Here describe accurately the denaturing warehouse, giving the height, width, and depth; the mixing tank or tanks and the capacity of each in gallons, also the size in height, width, and depth of the denaturing material room; the denaturing material tanks, and the capacity in gallons of each; also the openings of the denaturing warehouse and denaturing material room.) ——— ———,

Distiller.

EXAMINING OFFICER TO INSPECT WAREHOUSE.

Sec. 8. Upon receipt of the application and accompanying diagram the collector shall detail one of his deputies or some other officer who shall visit the distillery and make a careful examination of the proposed denaturing bonded warehouse.

Such officer shall ascertain whether or not said warehouse and mixing tanks and denaturing material room and tanks are constructed in conformity with the regulations, the statements made in the application, and the representations on the diagram.

Sec. 9. If the deputy collector finds that the statements in the application are true and that the denaturing warehouse and material room are constructed in conformity with the law and regulations, he shall make report and recommendation in the following form:

I hereby certify that I have visited the distillery premises described in the foregoing application for the approval of a warehouse in which to denature alcohol by ——— proprietor of distillery No. ——— in the district of ——— and have carefully examined the proposed warehouse and mixing tanks, and the denaturing material room and tanks; that I have measured said warehouse, room, and tanks, that I have examined said distillery premises, and the distillery and distillery bonded warehouses located thereon, and have found the statements and representations made in the application and diagram hereto attached to be in every respect true and correct.

I find that said proposed denaturing warehouse, mixing tanks, denaturing material room, and denaturing material tanks, and everything connected with the same are constructed in strict conformity with all requirements of the law and regulations.

I recommend that said denaturing warehouse be approved.

——— ———,

Deputy Collector ——— District of———.

This report shall be affixed to the application.

APPROVAL OF WAREHOUSE.

Sec. 10. The collector shall examine the deputy's report and if, after such examination, he is satisfied that the warehouse and all its parts are constructed in conformity with the law and regulations, he shall indorse his approval on the application and shall transmit the original, together with the diagram, to this office.

If the Commissioner of Internal Revenue is satisfied, after examining the application and reports, that the denaturing warehouse is situated and constructed in compliance with the law and regulations, he shall approve same and notify the collector of said approval.

DENATURING WAREHOUSE BOND TO BE GIVEN.

Sec. 11. After receipt of notice of the approval of said warehouse the distiller may withdraw from his distillery warehouse, free of tax, alcohol of not less than 180 degrees proof or strength, and may denature same in said denaturing warehouse in the manner hereinafter indicated, provided he shall first execute a bond in the form prescribed by the Commissioner of Internal Revenue, with at least two sureties, unless, under the authority contained in an act approved August 13, 1894, a corporation, duly authorized by the Attorney-General of the United States to become a surety on such bond, shall be offered as a sole surety thereon. The bond shall be for a penal sum of not less than double the tax on the alcohol it is estimated the distiller will denature during a period of thirty days, and in no case is the distiller to withdraw from bond for denaturing purposes and have in his denaturing warehouse in process of denaturation a quantity of alcohol the tax upon which is in excess of the penal sum of the bond.

Sec. 12. If, at any time, it should develop that the denaturing warehouse bond is insufficient the distiller must give additional bond.

Sec. 13. The bond herein provided for must be executed before the distiller can withdraw from distillery bonded warehouse, free of tax, alcohol to be denatured, and if he desires to continue in the business of denaturing alcohol, said bond must be renewed on the first day of May of each year or before any alcohol is withdrawn from bond for denaturing purposes. It must be executed in duplicate in accordance with instructions printed thereon. One copy is to be retained by the collector and one copy is to be transmitted to the Commissioner of Internal Revenue.

It shall be in the following form:

DENATURING WAREHOUSE BOND.

Know all men by these presents: That we, —— —— of ——, as principal, and —— —— of ——, as sureties, are held and firmly bound to the United States of America in the full and just sum of —— dollars, lawful money of the United States; to which payment, well and truly to be made, we bind ourselves jointly and severally, our several heirs, executors, and administrators, firmly by these presents.

Sealed with our seals and dated the —— day of ——, 190—.

The condition of the foregoing obligation is such that whereas the above bounden principal, under the provisions of the act of June 7, 1906, has constructed a warehouse for denaturing alcohol on the premises of distillery No. ——, situated at —— in the county of ——, State of ——, and said warehouse has been duly approved; and whereas said principal intends to withdraw from the distillery bonded warehouse belonging to said distillery and situated on the distillery premises, alcohol free of tax for the purpose of denaturing same in the denaturing warehouse;

Now, therefore, if the aforesaid principal shall *immediately* upon the withdrawal from the distillery bonded warehouse aforesaid of all alcohol intended for denaturing purposes transfer same to the denaturing warehouse aforesaid, and in said denaturing warehouse, denature said alcohol in accordance with the terms of the entry for withdrawal of same and in conformity with the law and all rules and regulations duly prescribed in relation to the denaturing of alcohol; and if said principal shall in the transferring from distillery warehouse to denaturing warehouse, and in the handling and disposing of said alcohol, comply with all the law and regulations aforesaid; if he shall pay the tax of one dollar and ten cents per proof gallon on all alcohol withdrawn by him from distillery bonded warehouse free of tax for denaturing purposes and disposed of in any manner, either in transit from the distillery bonded warehouse to the denaturing warehouse or after it has been deposited in the denaturing warehouse, without first having denatured said alcohol in such manner as may have been prescribed by the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, and if he shall pay all penalties incurred by him and all fines imposed on him for violation of any of the provisions of the law relating to the withdrawal of, transferring of, denaturing of, and disposing after denaturation of alcohol, withdrawn free of tax, then this obligation is to be void, otherwise, to remain in full force and effect.

——— ——— SEAL.
——— ——— SEAL.
——— ——— SEAL.

Sec. 14. The collector, upon receipt of the bond, shall examine same and investigate as to the sureties thereon.

If he finds the bond properly executed and the sureties sufficient, he shall approve the bond, and thereafter, during the life of the bond, the distiller may withdraw from his distillery warehouse, free of tax, alcohol to be denatured under such regulations as may hereinafter be prescribed.

CONDITIONS UNDER WHICH ALCOHOL IS WITHDRAWN.

Sec. 15. Not less than three hundred (300) wine gallons of alcohol can be withdrawn at one time for denaturing purposes.

When a distiller, who is a producer of alcohol of not less than 180 degrees proof and who has given the denaturing warehouse bond as aforesaid, desires to remove alcohol from the distillery bonded warehouse for the purpose of denaturing, he will himself, or by his duly authorized agent, file with the collector of internal revenue of the district in which the distillery is located, the following notice in triplicate:

NOTICE OF INTENTION TO WITHDRAW FOR TRANSFER TO DENATURING BONDED WAREHOUSE.

——, ——, 190—.

—— ——,

Collector —— *District of* ——

SIR: The undersigned distiller and owner of —— packages of alcohol, the serial numbers of which are ——, produced at distillery No. ——, in the —— district of ——, and now stored in the distillery bonded warehouse No. —— at said distillery, desires to withdraw same under section 1 of the act of June 7, 1906, for denaturing purposes, and requests that said spirits be regaged.*

Respectfully,

—— ——, *Distiller.*

Sworn to before me this —— day of ——, 190—

—— ——. [SEAL.]

Upon the receipt of such notice the collector will at once append to each copy the following:

COLLECTOR'S ORDER TO GAUGER.

OFFICE OF COLLECTOR OF INTERNAL REVENUE,
—— DISTRICT, ——.

SIR: You will proceed to distillery warehouse No. ——, of ——, at ——, and there inspect and gauge, according to law and regulations, the alcohol which —— desires to withdraw and transfer to denaturing bonded warehouse, and you will mark upon each package so regaged the number of wine gallons and proof gallons therein contained, and you will make report of your gauging on the certificate hereunto appended, and sign and deliver same to applicant.

—— ——,
Collector.

SEC. 16. Upon the receipt of the foregoing the officer designated will at once proceed carefully and thoroughly to inspect each package, ascertaining the actual wantage, proof, and contents without reference to the marks on the casks. In case the spirits are withdrawn on day of entry, regauge is not necessary, and the entry gauge shall be accepted. He will make return on each copy of the order for inspection in the following form:

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*If spirits are withdrawn same day as entered omit regage.

GAUGER'S REPORT OF SPIRITS GAUGED.

I hereby certify that pursuant to the above order the following-described spirits deposited in distillery bonded warehouse No. ——— by ——— ——— on the ——— day of ——— 190— have been inspected and gauged by me this ——— day of ——— 190— and found to be as follows:

Contents When Deposited in Warehouse.								Contents When Application for Withdrawal is Made.				
Number of Packages.	Marks and Serial Numbers of Packages.	Numbers of Warehouse Stamps.	Wine Gallons.	Degree of Proof.	Proof Gallons.	Taxable Gallons.	Amount of Tax.	Wine Gallons.	Degree of Proof.	Proof Gallons.	Taxable Gallons.	Amount of Tax.

And I further certify that the difference between the quantity, as shown by the marks and stamps on the cask and the quantity as shown by my inspection, made in pursuance of the above order, is ——— wine, ——— proof, and ——— taxable gallons.

——— ———,
U. S. Gauger.

Upon receipt of the gauger's report the distiller will indorse thereon an entry for withdrawal for transfer to denaturing bonded warehouse, which shall be in the following form:

ENTRY FOR WITHDRAWAL FOR TRANSFER TO DENATURING BONDED WAREHOUSE.

——— DISTRICT, STATE OF ———.
———, ———, 190—.

The undersigned requests that the spirits described in the foregoing certificate and report of gauger, now in distillery bonded warehouse No. ——, owned by ———, and situated in ———, county of ———, State of ———, in the ——— district of said State, may be transferred therefrom and delivered into the denaturing bonded warehouse situated at my said distillery, to be denatured under the provisions of the act of June 7, 1906.

Number of Packages.	Marks and Serial Numbers of Packages.	Number of War'house Stamps.	Wine Gallons.	Degree of Proof.	Proof Gallons.	Taxable Gallons	Amount of Tax.

———,

Distiller.

TAX COLLECTED ON DEFICIENCY.

Sec. 17. Upon receipt of the foregoing entry for withdrawal, the collector shall examine same, and, if it shall appear from the report of regauge, as made by the gauger, that there is an excessive loss in any package, under the provision of the act of August 28, 1894, as amended by act of March 3, 1899, then the collector shall collect the tax on such deficiency and shall indorse upon each copy of the order for inspection permit for the delivery of the spirits to be transferred to denaturing bonded warehouse in the following form:

PERMIT FOR TRANSFER TO DENATURING BONDED WAREHOUSE.

Office of Collector of Internal Revenue,
—— District of the State of ———,
———, ——, 190—.

Sir: The tax on ——— gallons of the deficiency of ——— gallons ascertained under section 50 of the act August 28, 1894, as amended, as shown by the accompanying report of —— gauger, having been paid to me and good and sufficient denaturing bond, dated ———, 190—, having been executed as required by law and filed in this office, said bond covering all distilled spirits to be transferred from distillery bonded warehouse to denaturing bonded warehouse for denaturing purposes, you are hereby directed to deliver said spirits to ——— to be transferred by him in your presence and under your supervision to the denaturing bonded warehouse of said ——— on his distillery premises.

The gauger will affix the proper marks and brands in your presence.

——— ———, *Collector.*

To ——— ———, *Storekeeper.*

SPIRITS TRANSFERRED TO BE MARKED.

Upon receipt of the permit by the storekeeper the packages of distilled spirits described in notice of intention to withdraw may be withdrawn from distillery bonded warehouse without the payment of the tax, and may be transferred to the denaturing bonded warehouse on the distillery premises; but before the removal of said spirits from the distillery bonded warehouse, the gauger, in addition to marking, cutting, and branding the marks usually required on withdrawal of spirits from warehouse, will legibly and durably mark on the head of each package, in letters and figures not less than one-half an inch in length, the number of *proof* gallons then ascertained, the date of the collector's permit, the object for which the spirits were withdrawn, and his name, title, and district.

Such additional marks may be as follows:

Withdrawn under permit issued Jan'y 10, 1907
For Denaturing Purposes
Proof gallons, 84
William Williams, U. S. Gauger,
5th Dist. Ky.

ENTRIES IN RECORD 18 AND REPORTS 86 AND 87.

Sec. 18. In his record 18 the storekeeper will enter said packages of spirits in *red ink* and will show that they were withdrawn free of tax for denaturing purposes. The storekeeper's reports on Forms 86 and 87 shall also show that the spirits were withdrawn for denaturing purposes and without the payment of the tax under the provisions of the act of June 7, 1906.

Immediately upon the withdrawal of the spirits, as above indicated, the storekeeper will transmit the duplicate permit to the collector, who will note upon the original permit in his possession the withdrawal of the spirits therein mentioned.

COLLECTOR'S 94a.

Sec. 19. The collector will take credit for all spirits so withdrawn, on the appropriate line of his bonded account (Form 94a), for the month during which such withdrawals were made.

He will also make proper entry on the inside page of that account as to the quantity covered by each permit, and will forward each of such duplicate permits (with the distiller's entry for withdrawal) with his bonded account as a voucher for such entry.

SPIRITS TRANSFERRED TO DENATURING BONDED WAREHOUSE.

Sec. 20. When the packages of spirits are marked and branded in the manner above indicated they shall at once in the presence and under the supervision of the storekeeper, be transferred to the denaturing bonded warehouse.

RECORD OF SPIRITS RECEIVED IN DENATURING BONDED WAREHOUSE.

Sec. 21. The officer in charge of the denaturing bonded warehouse shall keep a record of the spirits received in said denaturing bonded warehouse from the distillery bonded warehouse and the spirits delivered to the distiller for denaturing purposes.

Upon the *debit* side of said record, in columns prepared for the purpose, there shall be entered the date when any distilled spirits were received in denaturing bonded warehouse, the date of the collector's permit, the date of withdrawal from distillery bonded warehouse, the number of packages received, the serial numbers of the packages, the serial numbers of the distillery warehouse stamps, and the wine and proof gallons.

Upon the *credit* side of said record shall be entered the date when any spirits were delivered to the distiller for denaturing purposes, the date of the collector's permit for withdrawal, the date of withdrawal from distillery bonded warehouse, the number of packages so delivered, the serial numbers of the packages, the serial numbers of the distillery warehouse stamps, and the wine and proof gallons.

Immediately upon the receipt of any distilled spirits in the denaturing bonded warehouse, and on the same day upon which they are received, the officer must enter said spirits in said record.

Likewise, on the same date upon which any spirits are delivered to the distiller for denaturing purposes, said spirits must be entered on said record.

Sec. 22. A balance must be struck in the record described in above section at the end of the month showing the number of packages and quantity in wine and proof gallons of spirits on hand in packages on the first day of the month, the number of packages and quantity in wine and proof gallons received during the month, the number of packages and quantity in wine and proof gallons delivered to the distiller during the month, and the balance on hand in packages and wine and proof gallons at the close of the month.

RETURN ON FORM 86b.

Sec. 23. On all days on which any spirits are entered into the denaturing bonded warehouse, or on which any spirits are delivered to the distiller for denaturing purposes, the officer must make in duplicate a return on Form 86b as follows:

SPIRITS ENTERED IN DENATURING BONDED WAREHOUSE AND DELIVERED TO DISTILLER FOR DENATURATION.

RETURN for the —— day of —— 190— of distilled spirits entered into and withdrawn from denaturing bonded warehouse belonging to distillery No ——, carried on by —— ——, in the —— collection district of the State of ——.

ENTRIES.

Number Packages.	Serial Number Packages.	Serial Number D. W. S.	Date of Permit.	Date of Withdrawal	W. G.	P G

DELIVERIES TO DISTILLER FOR DENATURING PURPOSES.

Number Packages.	Serial Number Packages.	Serial Number D. W. S.	Date of Permit.	Date of Withdrawal.	W. G.	P. G

I hereby certify that the distilled spirits above reported were deposited into said denaturing bonded warehouse or were delivered to the distiller for denaturing purposes (as the case may be) in my presence, and that the information given concerning the serial numbers and contents of the packages, and the serial numbers of the stamps, was obtained by me on actual examination of the marks, brands, and stamps on said packages and not from any return made by the gauger.

—— ——,

U. S. Officer.

Dated at —— this —— day of ——, 190—.

MONTHLY RETURN OF SPIRITS ENTERED IN WAREHOUSE AND DELIVERED TO DISTILLER.

Sec. 24. The officer in charge of the denaturing bonded warehouse must also make in duplicate at the end of each month and forward to the Collector of Internal Revenue a monthly return to be a transcript of and to be made up from the officer's record 18b.

Said return must show in detail the spirits deposited in the denaturing bonded warehouse, also the spirits delivered to the distiller for denaturing purposes and the spirits remaining in the denaturing bonded warehouse at the end of the month. Separate entries must be made of each day's work and the spirits must be described in the same manner as they are in the return 86b and the book, Form 18b.

OFFICE FORM 15b.

Sec. 25. Collectors, in whose districts alcohol is being withdrawn from bond for denaturing purposes, shall provide themselves with a record (Office Form 15b) in which shall be kept the individual account of each distiller in the district who has qualified for the purpose of denaturing alcohol. This record is to be made up from reports on Form 87b. It must show the date upon which any spirits were deposited in denaturing warehouse, the serial numbers of the packages deposited, the number of packages and the proof gallons. Said record must likewise show in detail the deliveries to the distillers for denaturing purposes.

DENATURING AGENTS.

COMPLETELY DENATURED ALCOHOL.

Sec. 26. Unless otherwise specially provided, the agents used for denaturing alcohol withdrawn from bond for denaturing purposes shall consist of methyl alcohol and benzine in the following proportions: To every one hundred parts by volume of ethyl alcohol of the desired proof (not less than 180°) there shall be added ten parts by volume of approved methyl alcohol and one-half of one part by volume of approved benzine; for example, to every 100 gallons of ethyl alcohol (of not less than 180° proof) there shall be added 10 gallons of approved methyl alcohol and 1/2 gallon of approved benzine. Alcohol thus denatured shall be classed as completely denatured alcohol.

Methyl alcohol and benzine intended for use as denaturants must be submitted for chemical test and must conform to the specifications which shall be hereafter duly prescribed.

DENATURANTS DEPOSITED IN WAREHOUSE.

Sec. 27. As the distiller's business demands, he may bring into the denaturing bonded warehouse, in such receptacles as he may wish, any authorized denaturant. Such denaturants shall at once be deposited in the material room; thereafter they shall be in the custody and under the control of the officer in charge of the warehouse. Before any denaturant is used it must be dumped into the appropriate tank and after the contents have been thoroughly mixed, a sample of one pint taken therefrom. This sample must be forwarded to the proper officer for analysis. The officer will then securely close and seal the tank.

No part of the contents of the tank can be used until the sample has been officially tested and approved, and report of such test made to the officer in charge of the warehouse.

If the sample is approved the contents of the tank shall, upon the receipt of the report, become an approved denaturant and the officer shall at once remove the seals and place the tank under government locks.

If the sample does not meet the requirements of the specifications, the officer shall, upon the receipt of the report of non-approval, permit the distiller, provided he desires, to treat or manipulate the proposed denaturant so as to render it a competent denaturant. In such case another sample must be submitted for approval. If the distiller does not desire to further treat the denaturant, the officer shall require him immediately to remove the contents of the tank from the premises.

RECORD OF DENATURANTS RECEIVED.

Sec. 28. The officer shall keep a denaturing material room record. This record shall show all material entered into and removed from the denaturing material room.

There shall be proper columns on the *debit* side in which are to be entered the date when any material is received, the name and residence of the person from whom received, the kind of material, the quantity in wine gallons, and, if methyl alcohol, in proof gallons, the date upon which the material was dumped into the tank, the number of the tank, the date upon which sample was forwarded, and the number of the sample, and the result of the official test.

On the *credit* side of said record shall be entered, in proper columns, the date upon which any material was removed from the denaturing material room for denaturing purposes, the kind of material, the number of the tank from which taken, the number of the sample representing the tank and sent for official test, the number of wine gallons, and, if methyl alcohol, the number of proof gallons.

MONTHLY RETURNS OF DENATURANTS RECEIVED.

Sec. 29. A balance shall be struck in this record at the end of each month whereby shall be shown the quantity of material of each kind on hand in the denaturing material room on the first day of the month, the quantity received during the month, the quantity rejected and removed from the premises during the month, and the quantity delivered to the distiller for denaturing purposes during the month, and the quantity on hand at the end of the month.

The officer shall, at the end of each month, prepare in duplicate, sign, and forward to the collector of internal revenue a report which shall be a transcript of said record

DISTILLER TO KEEP RECORD OF DENATURANTS.

Sec. 30. The distiller shall also keep a record, in which he shall enter the date upon which he deposits any material in the tanks of the denaturing material room; the name and address of the person from whom said material was received, and the kind and quantity of the material so deposited; also he shall enter in said record the date upon which he receives any material from the denaturing material room, the kind and quantity of such material so received and the disposition made of same.

NOTICE OF INTENTION TO DENATURE SPIRITS.

Sec. 31. The distiller shall, before dumping any spirits or denaturants into the mixing tank, give notice to the officer in charge of the denaturing warehouse in proper form in duplicate, and enter in the proper place thereon (in the case of distilled spirits) and in the proper column the number of the packages, the serial numbers of same, the serial number of the warehouse stamps, the contents in wine and proof gallons and the proof as shown by the marks, the date of the withdrawal gauge, and by whom gauged.

In case of denaturing agents he shall enter in the proper place and in the proper columns the number of gallons, the kind of material, and the number of the denaturing material tank from which same is to be drawn.

The contents of the several packages of alcohol, as shown by the withdrawal gauge, shall be accepted as the contents of said packages when dumped for denaturing purposes unless it should appear from a special showing made by the distiller that there has been an accidental loss since withdrawal from distillery bonded warehouse.

Upon receipt of this notice the officer in charge of the denaturing warehouse shall, in case of the packages of alcohol, inspect same carefully to ascertain whether or not they are the packages described in the distiller's notice. He will then cut out that portion of the warehouse stamp upon which is shown the serial number of the stamp, the name of the distiller, the proof gallons, and the serial number of the package. These slips must be securely fastened to the form whereon the gauging is reported and sent by the officer with his return to the collector.

TRANSFER OF DENATURANTS TO MIXING TANKS.

Sec. 32. The distiller, unless pipes are used, as herein provided, shall provide suitable gaged receptacles, metal drums being preferred, with which to transfer the denaturing agents from the material tanks to the mixing tanks. These receptacles must be numbered serially and the number, the capacity in gallons and fractions of a gallon, the name of the distiller, and the number of the denaturing bonded warehouse marked thereon in durable letters and figures. They shall be used for transferring denaturing material from the material tanks to the mixing tanks and for no other purpose. The distiller must also provide suitable approved sealed measures of smaller capacity. The gauged receptacles are to be used where the quantity to be transferred amounts to as much as the capacity of the smallest gauged receptacle in the warehouse. The measures are to be used only when the quantity of material to be transferred is less than the capacity of the smallest gauged receptacle.

Sec. 33. The distiller may provide metal pipes connecting the material tanks and the mixing tanks and the denaturant may be transferred to the mixing tanks through these pipes. Such pipes must be supplied with valves, cocks, faucets, or other proper means of controlling the flow of the liquid, and such valves, cocks, or faucets must be so arranged that they can be securely locked, and the locks attached thereto must be kept fastened; the keys to be retained by the officer in charge, except when the denaturing material is being transferred to the mixing tanks.

In the event pipes are used as above provided, the glass gauges affixed to the material tanks must be so graduated that tenths of a gallon will be indicated.

Before any material is transferred from a material tank to a mixing tank the officer must note the contents of the material tank as indicated by the glass gauge. He will then permit the denaturant to flow into the mixing tank until the exact quantity necessary to denature the alcohol, as provided by the regulations, has been transferred. This he will ascertain by reading the gauge on the material tank before the liquid has begun to flow and after the flow has been stopped. He should verify the quantity transferred by reading the gauge on the mixing tank before and after the transfer.

Sec. 34. The officer in charge of the denaturing warehouse will be held strictly accountable for any errors in the quantities of denaturants added. It is important that his measurements should be absolutely correct. He must know that the measures and the gauged receptacles provided by the distiller and the graduated gauges affixed to the tanks are correct. He must from time to time apply such tests to these measures, gauged receptacles, or graduated gauges, as the case may be, as will satisfy him that they are correct. If he finds the measures, gauged receptacles, or graduated gauges to be incorrect, he shall refuse to permit the distiller to transfer any denaturant to the mixing tanks until appliances have been provided whereby the exact quantity of denaturants used may be ascertained.

The distiller must provide all scales, weighing beams, and other appliances necessary for transferring the denaturing materials, gauging or handling the alcohol, or testing any of the measures, receptacles, or gauges used in the warehouse, and also a sufficient number of competent employees for the work.

CONTENTS OF MIXING TANK TO BE PLUNGED.

Sec. 35. The exact quantity of distilled spirits contained in the packages covered by the distiller's notice having been ascertained by the officer and the spirits having been dumped into the mixing tank, and the quantities of the several denaturants prescribed by the regulations having been ascertained by calculation and added as above provided to the alcohol in the mixing tank, the officer must cause the contents of the tank to be thoroughly and completely plunged and mixed by the distiller or his employees.

OFFICER TO MAKE RETURNS OF DUMPED MATERIAL.

Sec. 36. The officer will make return on the proper form, wherein he will show the number of packages of distilled spirits inspected by him and dumped in his presence by the distiller, the serial numbers of said packages, the serial numbers of the warehouse stamps affixed to said packages, the proof gallon contents of said packages, and the name of the gauger who made the withdrawal gauge.

He shall also report on said form the number of drums of the several kinds of denaturants gauged by him and dumped in his presence, the serial numbers of said drums, the quantity in wine gallons, and, in the case of wood alcohol, the quantity in proof gallons of each kind of denaturant gauged and dumped, the serial numbers of the tanks from which the denaturants were drawn, and the tank sample number of said denaturant.

DRAWING OFF AND GAUGING DENATURED PRODUCT.

Sec. 37. The distiller may from time to time, as he wishes, in the presence of the officer, draw off from the tank or tanks the denatured produce in quantities of not less than 50 gallons at one time, and the same must at once be gauged, stamped, and branded by the officer and removed from the premises by the distiller.

KIND AND CAPACITY OF PACKAGES USED.

Sec. 38. He may use packages of a capacity of not less than five gallons or not more than one hundred and thirty-five (135) gallons, and each package must be filled to its full capacity, such wantage being allowed as may be necessary for expansion.

All packages used to contain completely denatured alcohol must be painted a *light green*, and in no case is a package of any other color to be used.

ALCOHOL TO BE IMMEDIATELY DENATURED.

Sec. 39. No alcohol withdrawn from distillery warehouse for denaturing purposes shall be permitted to remain in the denaturing bonded warehouse until after the close of business on the second day after the said alcohol is withdrawn, but all alcohol so withdrawn must be transferred, dumped, and denatured before the close of business on said second day.

APPLICATION FOR GAUGE OF DENATURED ALCOHOL.

Sec. 40. When the process of denaturing has been completed and the distiller desires to have the denatured alcohol drawn off into packages and gauged, he shall prepare a request for such gauge on the proper form. The request shall state as accurately as practicable the number of packages to be drawn off and the number of wine and proof gallons contents thereof.

This notice shall be directed to the collector of internal revenue, but shall be handed to the officer on duty at the denaturing bonded warehouse.

Sec. 41. If the officer shall find upon examination of the proper record that there should be on hand the quantity of denatured alcohol covered by said notice, he shall proceed to gauge and stamp the several packages of denatured alcohol in the manner herein prescribed, and shall make report thereof on the proper form.

In no case will the officer gauge and stamp denatured alcohol the total quantity in wine gallons of which taken together with any remnant that may be left in the denaturing tank exceeds in wine gallons the sum of the quantity of distilled spirits and denaturants dumped on that day and any remnant brought over from previous day.

HOW DENATURED ALCOHOL SHALL BE GAUGED.

Sec. 42. The gauging of denatured alcohol shall, where it is practicable, be by weight. The officer shall ascertain the tare by actually weighing each package when empty. Then, after each package has been filled in his presence, he shall ascertain the gross weight, and, by applying the tare, the net weight.

He shall then ascertain the proof in the usual manner, and by applying the proof to the wine gallons content the proof gallons shall be ascertained.

The regulations relating to the gauging of rectified spirits, so far as they apply to apparent proof and apparent proof gallons, shall apply to denatured spirits. Where it is for any reason not practicable to gauge denatured alcohol by weight, using the tables that apply in the case of the gauging of distilled spirits, the gauging shall be by rod.

RETURN ON FORM 237a.

SEC. 43. Having gauged each of said packages, the officer shall make return on Form 237a, whereon he shall first certify that he has carefully examined the distiller's denaturing account, and that the aggregate contents of the several packages embraced in said return, added to any balance that may be on hand after they are withdrawn, does not exceed in proof gallons the quantity shown to be in the mixing tank by the distiller's denaturing account. Usually there will be a slight loss in proof gallons in process of denaturation. If there is a material loss, however, the officer should ascertain the cause and should include the explanation in his report.

The return must also show in the proper columns in detail the capacity of each package, its gross weight, tare, net weight, if gauged by weight, indication, temperature, net wine gallons contents, proof, proof gallons contents, apparent proof, apparent proof gallons contents, the serial number of the denatured alcohol stamp affixed to the package, and the serial number of the package.

This return must be in duplicate, and must be forwarded to the collector of the district.

MANNER OF MARKING HEADS OF PACKAGES.

SEC. 44. *Upon each head* of the package shall be stenciled in *red* letters, of not less than 1½ inches in length by 1 inch in width, the words "DENATURED ALCOHOL."

Upon the stamp head of the package there shall be stenciled the serial number of the package, the name of the distiller denaturing the spirits, the number of the denaturing bonded warehouse at which the spirits were denatured, and the district and State in which it is located, the date upon which the contents of the package were denatured, and the serial number of the denatured alcohol stamp.

PACKAGES TO BE NUMBERED SERIALLY.

Sec. 45. Packages of denatured alcohol must be numbered serially as they are withdrawn and gauged. The serial number for every denaturing bonded warehouse must begin with number 1 with the first cask denatured, and no two or more packages denatured at the same denaturing bonded warehouse shall be numbered with the same number. A change of person or persons operating a distillery and denaturing bonded warehouse will not be taken to require a new series of numbers for the packages of spirits thereafter denatured at such warehouse.

STAMPS FOR DENATURED ALCOHOL.

Sec. 46. The following form of stamp for denatured alcohol is hereby prescribed:

STAMP FOR DENATURED ALCOHOL, NO. ——.

Issued by —— ——, collector of the —— district, State of ——, to —— ——, denaturer of alcohol in said collection district, ——, ——, 19—, —— proof gallons, —— wine gallons.

—— ——.
U. S. Officer.

These stamps are to be made of white paper, the lettering to be red. They are to be bound in book form, each book containing 150 stamps, only one denomination being contained in each book. The denominations are to be 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, and 130 gallons, respectively, with proper number coupons attached to each, and each coupon representing one gallon.

In using the coupons on said stamps the same rule will be followed in dealing with fractional parts of gallons as are observed in the case of rectifier's stamps; that is to say, if the fraction is less than five-tenths of a gallon it must be dropped, and if it is more than five-tenths it is called the next unit above. Connected with each stamp is its corresponding stub, which the officer must fill out in accordance with the facts in the case.

The stamp must be signed by the officer, and he will enter upon it the date upon which he affixes it to the package, the number of wine and proof gallons, the number of the denaturing bonded warehouse, and the name of the denaturer.

Sec. 47. Stamps for denatured alcohol will be intrusted to the officer assigned to the denaturing bonded warehouse. He must keep these stamps continuously in his possession, and when not in actual use the book must be deposited in a safe and secure place in the denaturing bonded warehouse under lock and key, to which no one shall have access at any time except himself.

The officer must make a daily report to the collector of all denatured alcohol stamps used, and for whom used.

DISPOSITION OF BOOKS, STUBS, ETC.

Sec. 48. When all the stamps in any book have been used, the book with the stubs will be returned to the collector, who shall forward it to this office. The stubs and unused coupons must remain in the book.

Officers are advised that they will be held strictly responsible for all denatured alcohol stamps delivered to them, and they are cautioned against affixing such stamps to packages which do not correctly represent the character of the contents. They must know that all the statements on the heads of the packages are strictly true.

DUTIES OF OFFICER IN REGARD TO MIXING TANK.

Sec. 49. The mixing tank is absolutely under control of the officer in charge of the warehouse. If it becomes necessary for him to leave the denaturing bonded warehouse during the process of denaturing, he must close and lock all openings to said tank and must retain the key in his possession, and all other persons must leave the building.

When the work of the day is done the officer must ascertain the quantity in wine and proof gallons ot any remnant of denatured alcohol that may be on hand, and on each day before any further denaturing is done he must, before anything is dumped into the denaturing tank, ascertain the quantity in wine and proof gallons of any remnant that may be in the tank.

RECORD OF OPERATIONS TO BE KEPT BY OFFICER.

Sec. 50. The officer assigned to duty at the denaturing bonded warehouse shall, in a book prescribed for that purpose, keep a true and correct record of the operation at said denaturing bonded warehouse.

Said book shall show on the debit side, in the case of distilled spirits, the date upon which the spirits were dumped, the number of packages dumped, the serial numbers of said packages, the serial numbers of the warehouse stamps, the date of permit, the date of withdrawal from the distillery warehouse, the name of the officer who made the withdrawal gauge, the wine gallons and proof gallons. In the case of denaturing agents, said record must show on said *debit* side the date on which said denaturing agents were dumped, the kind of material, the number of the denaturing tank from which taken, the tank sample number of the denaturant, the date upon which the sample was inspected, the quantity in wine gallons, and, if methyl alcohol, the quantity in proof gallons dumped.

If there is more than one dump made during the day *separate* entries must be made for each dump, but the totals for the day must be carried forward and entered in the proper columns in *red* ink.

On the *credit* side of said record must be entered the denatured product drawn from dump. The entries must be made in the proper columns and must show the number of packages of denatured alcohol drawn from dump, the serial numbers of the denatured stamps, the date upon which said packages were withdrawn from dump and gauged, the number of wine gallons and the number of proof gallons, and to whom delivered and the hour removed from the denaturing premises.

If there is more than one lot drawn off and gauged during the day, a separate entry must be made for each lot, but the total wine and proof gallons drawn off and gauged for the day must be carried forward and entered in *red* ink in a column prepared for that purpose.

There must also be columns in said book in which to enter the remnant brought over from the previous day, the total quantity of distilled spirits and denaturants dumped during the day, the quantity withdrawn from dump and gauged during the day, and the quantity left in the mixing tank at the close of business.

DENATURED ALCOHOL TO BE REMOVED FROM WAREHOUSE.

Sec. 51. Not later than the close of business on the day following that upon which the work of drawing off and ganging the denatured spirits is completed, the distiller must remove said denatured alcohol from the denaturing bonded warehouse. He may either remove the alcohol to a building off the distillery premises, where he can dispose of it as the demands of the trade require, or he may dispose of it in stamped packages direct to the trade from the denaturing bonded warehouse.

RECORD SHOWING ALCOHOL RECEIVED AND DISPOSED OF TO BE KEPT BY DISTILLER.

Sec. 52. The distiller must keep a record (Form 52d and 52e) in which he shall show, respectively, all denatured alcohol received from the officer in charge of the warehouse and disposed of by him.

Upon the "Received" side he shall enter the date upon which he receives any denatured alcohol from the denaturing bonded warehouse, the number of packages received, the serial numbers of the packages, the date upon which the alcohol was denatured, the name of the officer, the kind and percentage of the denaturants used, the serial number of the denatured alcohol stamp, and the aggregate wine and proof gallons. These entries must be made on the same day the denatured alcohol is received.

On the "disposed of" side the distiller must show the date upon which he disposes of any denatured alcohol, the name and address of the person or firm to whom sold or delivered, if a manufacturer, the kind of a manufacturer, the kind and percentage of the denaturing agents used, the number of packages, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, and the aggregate wine and proof gallon contents.

These entries must be made before the goods are removed from the denaturing bonded warehouse, if sold direct from there, or from the salesroom of the distiller off the premises, if sold from there.

Sec. 53. Spaces and columns must be provided for at the bottom of said record wherein can be shown the quantity of denatured alcohol brought over in stock from the previous month, the quantity received during the month, the quantity disposed of during the month, and the quantity remaining on hand at the end of the month. In this statement must be shown the number of packages brought over, received, disposed of, and on hand, the serial numbers of said packages, the serial numbers of the denatured stamps, the wine gallons, and the proof gallons.

MONTHLY TRANSCRIPT.

Sec. 54. Before the tenth day of each month the distiller must prepare a complete transcript of this record, must swear to same, and must forward it to the collector of the district.

Said affidavit shall be in the following form:

I, ——— ———, do state on oath that I am ——— of denaturing bonded warehouse No. —— in the ——— district of ———, and the above is a true, correct, and complete statement of the denatured alcohol received by me from said denaturing bonded warehouse, of the denatured alcohol disposed of, to whom disposed of, and of the denatured alcohol on hand at the end of the month.

COLLECTORS TO KEEP ACCOUNTS WITH DENATURERS.

Sec. 55. Collectors must keep an exact account with each denaturer of alcohol on record (Form 39a) in such manner as to be constantly advised as to the state of the denaturer's business, and they must exercise such supervision over the issue of stamps for denatured alcohol as will prevent fraud in their use.

The entries in said record 39a must be made daily. Said entries are to be made from the officer's returns on Form 122a and 237a. Under the heading "Material dumped for denaturation" must be entered in the case of distilled spirits the date of the dumping, the number of packages, the serial numbers of the packages, the serial numbers of the warehouse stamps, the date of the collector's permit for withdrawal, the date of withdrawal from distillery bonded warehouse, the name of the withdrawal gauger, and the wine and proof gallons.

In the case of denaturants there must be entered in proper columns the serial numbers of the tanks from which the denaturants were drawn, the tank sample number of the denaturant, the dates upon which said samples were inspected, and the number of gallons of each of the several kinds of denaturants dumped.

Under the heading "Alcohol Denatured," in the proper columns, shall be entered the date of denaturation, the number of packages denatured and gauged, the serial numbers of said packages, the serial numbers of the denatured stamps attached to them, the name of the officer, and the quantity of alcohol in wine and proof gallons denatured and gauged.

Proper columns and spaces shall be provided at the bottom of this record where shall be entered at the end of each month the quantity in wine and proof gallons of denatured alcohol remaining in denaturing tanks brought over from previous month, the quantity of material dumped for denaturation during the month, the quantity drawn from the denaturing tank, gauged, and removed from the premises during the month, and the quantity left in the mixing tank at the end of the month.

DISTILLER'S RETURN TO BE COMPARED WITH COLLECTOR'S RECORD.

Sec. 56. The distiller's return on Form 52d should be compared with this record at the end of each month. The number of packages, serial numbers of the packages, and number of gallons received by the distiller from denaturing bonded warehouse should agree with the 39a as made up from the officer's 237a.

MANNER OF HANDLING AND TESTING SAMPLES OF DENATURANTS.

Sec. 57. When the distiller at any denaturing bonded warehouse has dumped into any material tank a quantity of a proposed denaturant as hereinbefore provided, the officer shall draw a sample from said tank. A heavy glass bottle, which must be provided by the distiller, shall be used as a container for said sample. The bottle must be securely closed and sealed, and a label affixed thereto, showing the serial number of the denaturing material tank from which the sample was taken, the date it was drawn from the tank, and the name of the officer sending it.

The sample shall be securely packed and sent by express to the most convenient laboratory for test. All expenses in connection with the forwarding of samples must be borne by the distiller.

As soon as practicable the necessary tests of the sample shall be made in the laboratory and report made of its character.

One copy of the report should be sent to the collector of internal revenue of the district, and the other should be sent to the officer in charge of the denaturing bonded warehouse.

Part II.

DEALERS IN DENATURED ALCOHOL AND MANUFACTURERS USING DENATURED ALCOHOL.

Sec. 58. Alcohol denatured by use of methyl alcohol and benzine as provided in section 26 of these regulations is to be classed as *Completely denatured alcohol.* Alcohol denatured in any other manner will be classed as *Specially denatured alcohol.*

DENATURED ALCOHOL NOT TO BE STORED ON CERTAIN PREMISES, AND NOT TO BE USED FOR CERTAIN PURPOSES.

Sec. 59. Neither completely nor specially denatured alcohol shall be kept or stored on the premises of the following classes of persons, to wit: dealers in wines, fermented liquors or distilled spirits, rectifiers of spirits, manufacturers of and dealers in beverages of any kind, manufacturers of liquid medicinal preparations, or distillers (except as to such denatured alcohol in stamped packages as is manufactured by themselves), manufacturers of vinegar by the vaporizing process and the use of a still and mash, wort, or wash, and persons who, in the course of business, have or keep distilled spirits, wines, or malt liquors, or other beverages stored on their premises. *Provided*, That druggists are exempt from the above provisions.

CAN NOT BE USED IN MANUFACTURING BEVERAGES, ETC.

Sec. 60. Anyone using denatured alcohol for the manufacture of any beverage or liquid medicinal preparation, or who knowingly sells any beverage or liquid medicinal preparation made in whole or in part from such alcohol, becomes subject to the penalties prescribed in section 2 of the act of June 7, 1906.

Under the language of this law it is held that denatured alcohol can not be used in the preparation of any article to be used as a component part in the preparation of any beverage or liquid medicinal preparation.

PERMITS REQUIRED.

Sec. 61. Persons who wish to deal in completely denatured alcohol must secure permits from the collector of internal revenue of the district in which the business is to be carried on.

Every person who sells or offers for sale denatured alcohol in the original stamped package shall be classed as a *wholesale dealer in denatured alcohol*, and denatured alcohol shall not be sold in quantities of five gallons or more except in the original stamped packages.

Every person who sells or offers for sale denatured alcohol in quantities of *less* than five gallons shall be classed as a *retail dealer in denatured alcohol.*

The same person may be both a wholesale and a retail dealer, but the retail and the wholesale business will be considered separate, and permits must be secured for each.

Collectors are authorized to issue permits on the forms herein prescribed upon application duly made.

Said permits are to be numbered serially in the same manner in which special-tax stamps are now numbered, and are to be on the forms herein prescribed.

APPLICATION FOR PERMIT TO BE FILED WITH COLLECTOR.

Sec. 62. A person, firm, or corporation desiring to secure a permit to sell denatured alcohol must make application on the following form:

[Form 11a.]

The undersigned, ——— ———, states on oath that he is a member of the firm (corporation) of ———, doing business at ———, and said firm (corporation) consists of — —— ——— and is located at ———, in the county of ——— and State of ———. The premises of said concern are located on ——— street, and are described as follows. ——— — and said premises constitute all of the premises used by ——— in ——— said business, that no part of said premises is used by anyone in the business of a distiller, manufacturer of wines or malt liquors, a dealer in wines, malt liquors, or distilled spirits (except druggists), a rectifier of spirits, a manufacturer of or dealer in any kind of beverages, a manufacturer of any liquid medicinal preparation, or a manufacturer of vinegar produced by any vaporizing process from mash, wort, or wash, or by any person (except druggists) who in the course of his business keeps or stores distilled spirits, wines, or malt liquors thereon.

Applicant binds himself and his —— to comply with the law and all the regulations relating to the handling and sale of denatured alcohol.

He desires to deal in denatured alcohol in the original stamped package (or in quantities of less than five gallons), and he therefore requests that a permit be issued to him to receive denatured alcohol in stamped packages upon his premises and to sell same in original stamped packages (or in quantities of less than five gallons).

(Signed) ——— ———

Subscribed and sworn to before me this —— day of ———, 190—.

——— ———

In the case of individuals the application must be signed and sworn to either by the individual himself or by his duly authorized attorney in fact, and either a general power of attorney or a power specially authorizing the attorney in fact to act must accompany the application.

In the case of corporations the application must be signed and sworn to by the duly authorized officer or agent of the corporation, and a certified copy of the minutes of the board of directors authorizing the party, either generally or specially, to perform the act must accompany the application.

PERMITS EXPIRE JUNE 30 EACH YEAR.

Sec. 63. Applications to deal in denatured alcohol must be made to the collector of internal revenue of the district in which it is proposed to do business on or before the first day of July of each year, or before any denatured alcohol is received on the premises, and said application will expire on the 30th of June ensuing.

In case a dealer in denatured alcohol moves his place of business before the expiration of the fiscal year for which the permit was issued he must make application for the transfer of his permit to the place to which he moves.

PERMITS TO BE CANCELED UNDER CERTAIN CONDITIONS.

Sec. 64. If it should appear on proper showing made at any time that the party to whom a permit to deal in denatured alcohol has been issued has wilfully violated any of the provisions of the law or regulations relating to the using or handling of denatured alcohol, it shall be the duty of the collector of internal revenue to cancel the permit.

Appeal for rehearing may be made to the Commissioner of Internal Revenue in any case where a permit has been canceled, and the Commissioner may, if he thinks the facts justify it, reverse the action of the collector in canceling the permit.

FORM OF PERMIT.

Sec. 65. The collector's permit will be in the following form:

This is to certify that, application having been made to me in due form, permission to engage in the business of wholesale (retail) dealer in denatured alcohol is hereby given to — — — ———, at — ——, on the following-described premises ————, said permit to expire on June 30, ———

Right to cancel this permit is hereby reserved, should it at any time appear on proper showing made that the said party has wilfully violated any of the provisions of law or regulations regarding denatured alcohol.

———. ——. ——,

Collector ——— District

COLLECTORS TO KEEP RECORD OF DEALERS, DENATURERS, ETC.

Sec. 66. Collectors shall keep a record (Book Form 10a), in which shall be entered the names of all distillers who have qualified as denaturers of alcohol in the district, and the names of all wholesale and retail dealers in denatured alcohol; also manufacturers using specially and those using completely denatured alcohol. Said record shall show the name of the party, his residence, and the date, number, and whether he is a dealer, distiller, or manufacturer. This record shall be open to public inspection.

WHOLESALE DEALERS TO KEEP RECORD.

Sec. 67. Wholesale dealers in denatured alcohol shall keep a record, in which they shall enter all the denatured alcohol received and disposed of by them.

On the received side they shall enter the date upon which the package of denatured alcohol was received, the name and address of the persons from whom received, the district and State in which the alcohol was denatured, the number of packages received, the serial numbers of the packages, the serial numbers of the stamps, and the wine and proof gallons.

These entries shall be made in said record upon the day on which the dealer receives the denatured alcohol and before it is removed from his premises or any of the packages are broken.

On the disposed-of side of said record the dealer shall enter the date upon which he disposes of any denatured alcohol, the name and address of the person to whom disposed of, whether the purchaser is manufacturer or dealer, the name of the denaturer and the district in which the alcohol was denatured, the number of packages, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, and the aggregate number of wine and proof gallons.

These entries must be made *before* the alcohol is removed from the premises.

In case the dealer is a retail dealer and the alcohol is charged off to himself as a retail dealer, the entries must be made in said record before the package is opened or any alcohol is drawn from it.

Columns and spaces must be arragned in said record in which at the end of the month the dealer must enter the number of packages, the serial numbers of the packages and the quantity in gallons of denatured alcohol on hand on the first day of the month, received during the month, disposed of during the month, and on hand at the end of the month.

WHOLESALE DEALER TO MAKE MONTHLY TRANSCRIPT.

Sec. 68. The dealer must make a transcript of this record each month, must swear to it before some officer authorized to administer oaths, and must forward it to the collector of the district before the 10th day of the ensuing month.

Said affidavit may be in the following form:

I ——— ———, do state on oath that I am ———, of the business of ———, wholesale dealer in denatured alcohol, and that the above is a true, correct, and complete transcript of the record showing the business done by ———, as such wholesale dealer in denatured alcohol, and that said record is in every respect a true and correct record of the business done by said dealer during the month of ———, 190—, and of the balance of alcohol on hand at the end of said month.

Subscribed and sworn to before me this —— day of ———.

——— ———.

RECORD ALWAYS OPEN TO INSPECTION OF OFFICERS.

Sec. 69. This record must be open at all times to the inspection of all Internal Revenue officers or agents. It must be preserved by the dealer for two years. Wholesale dealers in denatured alcohol must keep a sign in legible and durable letters posted in a conspicuous place on the outside of their building, as follows:

"Wholesale Dealer in Denatured Alcohol."

BILLS OF LADING, ETC., TO BE PRESERVED BY DEALERS.

Sec. 70. All denaturers of alcohol and wholesale dealers in denatured alcohol must preserve for two years all bills of lading; express receipts, dray tickets, and other similar papers showing shipment of denatured alcohol, and such papers must be submitted to any internal-revenue officer or agent who makes request for same for inspection.

ASSISTANCE TO BE FURNISHED OFFICERS.

Sec. 71. Dealers in denatured alcohol shall keep the permits issued to them posted in a conspicuous place. They must furnish internal-revenue officers or agents the help and all the facilities necessary to handle the packages of denatured alcohol when said officers are making inspections.

RETAIL DEALERS TO KEEP RECORD.

Sec. 72. Retail dealers in denatured alcohol shall keep a record, in which they shall enter the date upon which they receive any package or packages of denatured alcohol, the person from whom received, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, the wine and proof gallons, and the date upon which packages are opened for retail.

The transcript of each month's business as shown by this record must be prepared, signed, and sworn to and forwarded to the collector of internal revenue of the district in which the dealer is located before the 10th of the following month. This transcript must be signed and sworn to by the dealer himself or by his duly authorized agent.

LABELS TO BE PLACED ON RETAIL PACKAGES.

Sec. 73. Retail dealers in denatured alcohol must provide themselves with labels upon which the words "Denatured Alcohol" have been printed in plain, legible letters. The printing shall be red on white. A label of this character must be affixed by the dealer to the container, whatever it may be, in the case of each sale of denatured alcohol made by him.

STAMPS TO BE DESTROYED WHEN PACKAGE IS EMPTY.

Sec. 74. As soon as the stamped packages of denatured alcohol are empty the dealer or manufacturer, as the case may be, must thoroughly obliterate and completely destroy all marks, stamps, and brands on the packages.

The stamps shall under no circumstances be reused, and the packages shall not be refilled until *all* the marks, stamps, and brands shall have been removed and destroyed.

MANUFACTURERS USING COMPLETELY DENATURED ALCOHOL TO SECURE PERMIT.

Sec. 75. Manufacturers desiring to use completely denatured alcohol, such as is put upon the market for sale generally, may use such alcohol in their business subject to the following restrictions.

A manufacturer using less than an average of 50 gallons of denatured alcohol per month will not be required to secure permit from the collector or to keep records or make returns showing the alcohol received and used.

Manufacturers who use as much as 50 gallons of completely denatured alcohol a month must procure such alcohol in stamped packages, and before beginning business the manufacturer must make application to the collector of the proper district for permit, in which application he will state the exact location of his place of business, describing the lot or tract of land upon which the plant is located, and must keep the alcohol in a locked room until used.

Sec. 76. The permit shall be in the following form:

PERMIT TO MANUFACTURER TO USE COMPLETELY DENATURED ALCOHOL

It appearing upon application duly made by ——— ——— that, under the act of June 7, 1906, ——— ——— should be permitted to use completely denatured alcohol, in quantities of more than 50 gallons per month, at ———, factory of ——— ———, in the county of ———, State of ———, in the manufacture of ———, permission is hereby given said ——— ——— to procure completely denatured alcohol in stamped packages and use same in such manufacture at said place

This permit expires ——— ———, 190—.

——— ———,
Collector ——— *District* ———.

EVERY FACILITY FOR EXAMINATION TO BE AFFORDED OFFICERS.

Sec. 77. Denaturers of alcohol, dealers in denatured alcohol, and persons who use it must afford every facility to revenue officers and employees whose duty it is to make investigation as regards such alcohol. The premises upon which the alcohol is denatured or sold or in any manner handled must be open at all hours of the day or night (if the same should be necessary) to revenue agents, inspectors, and deputy collectors; and all books, papers, or records of every kind, character, or description relating to the alcohol handled by such persons must be submitted to any revenue officer for inspection and the officer must be permitted to make transcripts or copies of such books or papers, provided in the discharge of his duty he finds it necessary.

OFFICER TO TAKE SAMPLES.

Sec. 78. Should any revenue officer for any reason suspect that any beverage or liquid medicinal preparation contains denatured alcohol, he must secure samples of the suspected goods and forward them to his superior officer, who will forward them to the proper chemist for analysis. Such samples should be so marked as to identify them. Any internal-revenue officer is authorized to take samples of denatured alcohol, wherever found, and at such times as it may be deemed necessary, said samples to be submitted to the proper official for examination. These samples will, under no circumstances, be more than will be needed for analysis or examination.

PART III.

SPECIAL DENATURANTS.

Sec. 79. As the agents adapted to and adopted for use in complete denaturation render the alcohol denatured unfit for use in many industries in which ethyl alcohol, withdrawn free of tax, can be profitably employed, therefore, in order to give full scope to the operation of the law, special denaturants will be authorized when absolutely necessary. Yet the strictest surveillance must be exercised in the handling of alcohol incompletely or specially denatured.

FORMULA FOR SPECIAL DENATURANTS TO BE SUBMITTED TO THE COMMISSIONER.

Sec. 80. The Commissioner of Internal Revenue will consider any formula for special denaturation that may be submitted by any manufacturer in any art or industry and will determine (1) whether or not the manufacture in which it is proposed to use the alcohol belongs to a class in which tax-free alcohol withdrawn under the provisions of this act can be used, (2) whether or not it is practicable to permit the use of the proposed denaturant and at the same time properly safeguard the revenue. But one special denaturant will be authorized for the same class of industries, unless it shall be shown that there is good reason for additional special denaturants.

The Commissioner will announce from time to time the formulas of denaturants that will be permitted in the several classes of industries in which tax-free alcohol can be used.

APPLICATION FOR PERMITS TO USE SPECIAL DENATURANTS.

Sec. 81. Manufacturers desiring to use specially or incompletely denatured alcohol in their business must make application to the collector of internal revenue of the district in which the business is located. In this application the following information must be given: The location of the plant; the name and address of each partner or the corporate name, if a corporation; a complete description of each building on the manufacturing premises as to dimensions, partitions, apartments, or openings; a complete description of the room or place in which it is proposed to keep the denatured alcohol stored as to dimensions, openings, and kind of materials of which constructed; the kind of business carried on and in which it is proposed to use the denatured alcohol; the special denaturants desired to be used and the reasons for desiring to use such special denaturants; the quantity of denatured alcohol it is estimated will be used until the 1st of the next July following; and if alcohol is recovered in the process of manufacture, the manner in which it is recovered, its condition when recovered, and the percentage so recovered.

STOREROOM TO BE SET ASIDE—HOW CONSTRUCTED.

Sec. 82. A room or building must be prepared and set aside in which to store the denatured alcohol after it is brought upon the premises, and such room or building shall be numbered serially in each collection district.

Said room must be on the manufacturing premises, and it must be used for storage of denatured alcohol, alcohol recovered in the process of manufacture, for the work of restoring and redenaturing such recovered alcohol, and for no other purpose.

It must be securely constructed in such manner as to render entrance impossible during the absence of the person in whose charge it is placed.

The doors and windows must be so constructed that they may be securely fastened. All necessary openings must be under a prescribed lock, the key to be kept by the person designated to have charge of the storeroom.

A sign, "Denatured Alcohol Storeroom No. —," must be placed over the main door of the room.

FORM OF APPLICATION AND TO WHOM MADE.

Sec. 83. The application made to the collector by the manufacturer must be in duplicate and in the form prescribed below; and a diagram showing the buildings on the manufacturing premises and their relation to each other must accompany the notice:

NOTICE BY MANUFACTURERS.

Notice is hereby given that ——— ——— of the ——— of ———, county of ——— and State of ——— intend—, under the name or style of ——— ——— —, to carry on, after the ——— day of ——— 190—, on the premises owned by ——— ———, situate No ——— street, in the ——— of ———, county of ——— and ——— of ———.

(Name of all partners interested in the business, if a firm, or name of corporation if a corporation, with residence.)

(Particular description of the lot or tract of land on which the buildings used in the business are located.)

(Size and description of all buildings on the manufacturing premises and material of which constructed. Purpose for which used.)

(Statement of the title under which the premises on which the manufacturing business is situated is held and the name or names of the owners thereof.)

Said ——— ——— desires to use specially denatured alcohol, at ——— proof, in manufacture of the said ———, the alcohol to be denatured by the use of the following agents as denaturants, ———

———, and ha—— provided and set aside a store-room on said premises in which to store said denatured alcohol, said storeroom being described as follows: ——— ———

It is estimated that ——— proof gallons of denatured alcohol will be used in the manner indicated between the —— day of ——— and the —— day of July, 190—.

——— ———

——— ———

Subscribed and sworn to before me this —— day of ———, 190—.

——— ———

Sec. 84. This notice will be given in all cases before beginning business or before using specially denatured alcohol in said business, and on the first day of July of each succeeding year in cases where the business is continued.

The name of every person interested in the business as a partner must be stated in the proper space, except in the case of notices given by incorporated companies, when the names and addresses of the officers of the corporation should be given.

The signature to the notice when given by an individual must in all cases be made by the manufacturer in person, or in his name by his authorized agent or attorney in fact.

In case of a firm, the signature must be made in the firm name by a member of the firm or by some person duly authorized as above.

In case of a corporation, the signature must be made in the name and under the seal of the corporation by the proper officer thereof.

COLLECTOR TO CAUSE PLANT TO BE INSPECTED.

Sec. 85. Upon receipt of the foregoing notice the collector will, either by himself or one of his deputies, proceed to the manufacturing plant described in the application and notice and inspect same. He will ascertain whether or not the statements in the notice and representations on the accompanying diagram are true and correct, and if he finds they are, he will indorse on the notice the following:

> I hereby certify that I have examined the premises of ———, described in the within application and accompanying diagram, and I find the statements and representations therein made to be true and correct.
>
> ———,
>
> ——— *Collector*, ——— *District* ———.

COLLECTOR TO EXAMINE APPLICATION.

Sec. 86. One copy of the application will be retained by the collector and the other will be forwarded to the Commissioner of Internal Revenue. The collector will examine the application and will determine—

First. Whether alcohol withdrawn from bond free of tax under the provisions of this act can be used in the manufacture of the article or articles it is proposed to manufacture at said place.

Second. Whether the denaturants proposed have been authorized by the Commissioner of Internal Revenue for the class of industry in question.

Third. Whether the premises can, under these regulations, be used for the storage of denatured alcohol—that is to say, whether or not they come within one of the classes of premises upon which denatured alcohol can not be stored.

Fourth. Whether the room in which it is proposed to store the denatured alcohol to be brought upon the premises and used for manufacturing purposes, as indicated, is safe and secure and meets the requirements of the regulations.

If the collector finds favorably on all the above propositions he will approve the application.

Sec. 87. If the industry in which it is proposed to use the denatured alcohol has not been held by the Commissioner of Internal Revenue to be an industry in which alcohol withdrawn under the provisions of this act can be used, or if the proposed formula of denaturants has not been duly authorized, the collector will take no action upon the application until the Commissioner has passed upon it and has duly advised him.

MANUFACTURERS TO GIVE BOND.

Sec. 88. If the application is approved the manufacturer shall at once be notified, but before the use of specially denatured alcohol is permitted on the premises, or at the place designated in the application, the manufacturer shall file with the collector a bond in the prescribed form, said bond to be renewed annually on the first day of July and to run until the first day of the following July.

FORM OF MANUFACTURER'S BOND.

Know all men by these presents, that ——— ———, of ———, as principal, and ——— ———, of ——— and ——— ——— of ———, as sureties, are held and firmly bound unto the United States of America in the sum of ——— dollars, to be paid to the said United States; for the payment whereof we bind ourselves, our heirs, executors, and administrators, jointly and severally, firmly by these presents

Witness our hands and seals this ——— day ———, nineteen hundred and ———.

The condition of this obligation is such that whereas the abovebounden principal is engaged in the business of manufacturing ——— ——— at ———, in the county of ———, State of ———, and intends to use in said manufacture alcohol withdrawn from bond free of tax and denatured in the following manner: ——— said alcohol so denatured to be secured from any distiller with whom the said principal can make satisfactory arrangements and transported from denaturing bonded warehouse to said principal's manufacturing premises above described.

Now, therefore, if the entire quantity of alcohol so secured at denaturing bonded warehouse or warehouses is transported to the place of business of the said ——— ———, and is securely stored in the denatured alcohol storeroom designated and set aside as such at said place and is there safely kept until it is needed for use in the manufacture of ——— by said ——— ——— and is used by said ——— ——— for the purposes specified and for no other purposes, and if the said ———, or their agents or employes, shall faithfully comply with all the requirements and regulations prescribed by the Commissioner of Interna' Revenue and approved by the Secretary of the Treasury in relation to the transporting of denatured alcohol from denaturing bonded warehouses to manufacturing establishments, the storing of said alcohol on manufacturing premises, and the keeping of records and the making of returns and reports, then this obligation to be void, otherwise to remain in full force and effect.

And the obligors for themselves, their heirs, executors, administrators and assigns, do further covenant and agree with the United States, in case said denatured alcohol, or any part thereof is diverted from the purpose for which it is intended, either in transit from the denaturing bonded warehouse to the manufacturing establishment, or after it has been stored in said manufacturing establishment, or shall be used for any purposes other than those specified above well and truly to pay, or cause to be paid, to the collector aforesaid double the legal tax on the whole amount of alcohol so wrongfully diverted and used.

The true intent of this obligation is that it will operate both as a transporting and a warehousing bond. Liability under it is to attach as soon as *any* alcohol specially denatured at *any* denaturing bonded warehouse shall leave said warehouse to be transported to the manufacturing premises of the principal herein. It is to cover said alcohol while in transit to said manufacturing establishment and after it is stored in the designated storeroom at said establishment It is intended to save the United States harmless because of any neglect or wrongful act on the part of the principal or any of ——— agents or employees done in connection with or in relation to said denatured alcohol, no matter whether said act or acts be the independent act of the principal or his agents, or an act or acts done pursuant to a conspiracy or an agreement with some officer or agent of the United States.

——— ———.
——— ———.
——— ———.

Signed, sealed, and delivered in the presence of—

——— ———.
——— ———.

The penal sum of this bond shall be the amount of the tax on the estimated quantity of denatured alcohol that the manufacturer will use during the year the bond is intended to cover, and at no time shall the manufacturer have on his premises a quantity of denatured alcohol the tax upon which is more than one-half of the penal sum of the bond. The manufacturer may, at any time it may appear that the bond for any year is insufficient, give an additional bond.

There must be at least two sureties to the bond and they must make the usual affidavit on Form No. 33, unless under authority contained in the act of August 13, 1894, a corporation duly authorized in writing by the Attorney-General of the United States to do business under said act shall be offered as sole surety.

The Christian names of the signers must be written in the body of the bond and so signed to the bond. The residence of each signer must be stated in the body of the bond.

Each signature must be in the presence of two witnesses, who must sign their names as such, and a seal of wax or wafer must be attached to each signature.

COLLECTOR TO APPROVE BOND.

Sec. 89. The bond, after being duly executed, will be deposited with the collector of internal revenue, who will examine it carefully. He will also investigate as to the solvency of the sureties. If he finds the bond to be sufficient, he will approve it and forward it to the Commissioner of Internal Revenue, together with his certificate to the effect that he has examined the bond and finds it made in accordance with the regulations, and that the sureties are sufficient.

If upon receipt and examination of the bond the Commissioner approves it, he will notify the collector, and thereafter, during the life of the bond, it will be lawful for the manufacturer to receive and transport to his manufacturing premises from any distiller who is a denaturer of alcohol, alcohol denatured in the manner prescribed in the application and bond.

COLLECTOR TO ISSUE PERMIT.

Sec. 90. Upon the approval of the bond, the collector shall issue a permit to the manufacturer, which shall be numbered serially and shall be in the following form:

MANUFACTURER'S PERMIT.

This is to certify, whereas ——— ———, manufacturers of ———, in the county of ———, State of ———, on the ——— day of ———, 190--, made application for permit to use alcohol denatured in special manner, to wit, by the use of ———, and the said application having been approved, said manufacturers gave bond as required by law, and the same has been approved.

Therefore the said manufacturers are hereby authorized and permission is hereby given them to receive and have transported to their premises and stored in their designated storeroom for denatured alcohol, alcohol denatured in the manner above indicated.

This permit expires July 1, 190-.

——— ———,
Collector District ———.

MANUFACTURER TO GIVE NOTICE OF DENATURER FROM WHOM ALCOHOL IS SECURED.

Sec. 91. Manufacturers who have given bond and received the permit and are thereafter authorized under the restrictions herein prescribed to use alcohol denatured with special denaturants may secure from any distiller who is a denaturer of alcohol the alcohol to be used in said business.

The manufacturer shall give notice to the collector of the district in which his establishment is located in the following form in duplicate if the manufacturing establishment and the denaturing bonded warehouse at which the alcohol is denatured are in the same collection district, and in triplicate if they are in different districts.

——— ———

Collector, District of ———:

You are hereby notified that I have arranged with ——— ———, proprietor of distillery No. ——, located at ———, in the district of ———, to supply ——— ——— from denaturing bonded warehouse No. ——, located at ———, in the —— district of ———, with alcohol denatured in accordance with the terms of —— application approved on the —— day of ———, 190–, in the following manner, to wit: ——— Said alcohol to be used in the manufacture of ——— in ——— establishment located at ———, in the district of ———. The alcohol is to be transported to ——— premises by ——— and ———.

(Signed) ——— ———.

Upon receipt of this notice the collector shall retain one copy in his office. The other copy he shall forward to the Commissioner of Internal Revenue, and, if the manufacturing establishment and the warehouse at which the alcohol is to be denatured are in different districts, the third copy shall be forwarded to the collector of the district in which the denaturing bonded warehouse is located.

NOTICE TO OFFICER AT DENATURING BONDED WAREHOUSE.

Sec. 92. The collector of the district in which the denaturing bonded warehouse is located shall forward to the officer in charge of said warehouse a notice in the following form:

You are hereby notified that ——— ———, manufacturer of ———, located at ———, in the district of ———, ha— been duly authorized to use in the manufacture of said ——— at said establishment alcohol specially denatured in the following manner, ——— and the said ——— ha— given notice that —— he —— ha— arranged with ——— ———, proprietor of distillery No. ——, to supply alcohol so denatured from denaturing bonded warehouse No. ——, in the ——— District of ———.

You are hereby authorized to permit said distiller to withdraw from bond, free of tax, alcohol to be denatured in the manner indicated, the quantity to be withdrawn during the current fiscal year not to exceed ——— gallons.

——— ———,
Collector, District ——.

REGULATIONS PRESCRIBED IN CASE OF COMPLETELY DENATURED ALCOHOL TO APPLY.

Sec. 93. The regulations prescribing the manner in which alcohol is to be withdrawn from warehouse, transferred to denaturing bonded warehouse and dumped, the manner in which the denaturants are to be brought upon the premises, stored and tested, in the case of completely denatured alcohol, apply in case of specially denatured alcohol; likewise the regulations prescribing the manner in which completely denatured alcohol is to be drawn off, after being denatured, gauged, marked, etc., apply in case of specially denatured alcohol. In the case of specially denatured alcohol the following marks, in addition to those prescribed for completely denatured alcohol, must be put upon the stamp-head:

Denatured for ———, proprietor of storeroom for specially denatured alcohol, No. —— in the district of ———.

SPECIAL AND COMPLETE DENATURANTS NOT TO BE MIXED.

Sec. 94. In no case is completely denatured alcohol to be mixed with specially denatured alcohol and special denaturants are to be kept completely separate from denaturants used in complete denaturation. The officer in charge of the warehouse must be careful to see that denaturing material tanks are empty before any special or complete denaturing agents are dumped. Likewise he must be careful to see that the mixing tanks are empty before any dumps, either for special or complete denaturation, are made.

SPECIALLY DENATURED ALCOHOL TO BE AT ONCE PUT IN TRANSIT.

Sec. 95. As soon as specially denatured alcohol is gauged and the packages are properly marked and stamped, it must be removed from the denaturing bonded warehouse and put in transit to the manufacturer for whom it was denatured, and under no circumstances must any other disposition be made of any part of it.

REPORTS AT WAREHOUSE, ETC.

Sec. 96. Reports, records, etc., relating to the alcohol after it has been denatured, and to be made and kept by the officer and the distiller must, in the case of specially denatured alcohol, contain columns and spaces for showing and must show the name and address and number of the manufacturer to whom the alcohol was sold, and the following additional reports must be made by the officer and the distiller:

——— ———

Collector ——— *District of* ———.

You are hereby notified that I have this day delivered to ——— ———, proprietor of distillery No. ———, district of ———, the following packages of specially denatured alcohol.

Number of Packages.	Serial Number Packages.	Serial Number Stamps.	Wine Gallons.	Proof Gallons.

Said alcohol was denatured at ——— denaturing bonded warehouse No. ———, located at ———, in the ——— district of ———, and it was disposed of to ——— ———, proprietor of manufacturer's storeroom No. ———, located at ———, in the district of ———, in accordance with specifications as stated in the notice of ——— ———, 190–, and it has this day been forwarded to ——— ———, at ———, by ——— ———, there to be delivered to said manufacturer.

——— ———,

United States Officer.

This report shall be made in triplicate, one copy to be sent to the collector of the district in which the denaturing bonded warehouse is located, one to the collector of the district in which the manufacturing establishment is located, and one to the Commissioner of Internal Revenue.

NOTICE OF SHIPMENT OF SPECIALLY DENATURED ALCOHOL.

Sec. 97. The distiller shall prepare and forward a report in the following form:

——— ———,

Collector:

You are hereby notified that I have this day received from ——— ——— denaturing bonded warehouse No. ———, located at ———, in the ——— district of ———, the packages of specially denatured alcohol described below and have forwarded them to ——— ———, manufacturer of ———, and proprietor of manufacturer's storeroom for specially denatured alcohol No. ———, located at ———, in the district of ———.

Number of Packages.	Serial Number Packages.	Serial Number Stamps.	Wine Gallons.	Proof Gallons.

——— ———,

Proprietor of Distillery No. ———.

ALCOHOL TO BE PROMPTLY FORWARDED AND NOTICE OF RECEIPT GIVEN.

Sec. 98. It shall be the duty of the officer in charge and the distiller to see that the denatured alcohol is promptly delivered from the denaturing bonded warehouse to the common carrier.

The manufacturer must immediately upon receipt of the alcohol store it in his designated storeroom for denatured alcohol, and must at once prepare report in the following form:

NOTICE OF RECEIPT OF ALCOHOL.

OFFICE OF ——— ———,
——— ———.

——— ———,
Collector ——— *District* ———.

You are hereby notified that I have this day received from ——— ———, carrier, the packages of denatured alcohol hereinafter described, received at ——— on the ——— day of ———, 190—, by ——— ———, from ——— ———, proprietor of distillery No. ———, in the ——— district of ———, and denatured at ——— in denaturing bonded warehouse No. ———, in the ——— district of ——— in accordance with the formula authorized on the ——— day of ———, 190—. Said alcohol has been stored in designated storeroom for specially denatured alcohol on ——— premises and will not be removed from there except as it is needed for use in the manufacture of ———. Said storeroom is in the custody and control of ——— ———.

Respectfully,

——— ———, *Manufacturer.*

This report shall be made in duplicate, one copy to be forwarded to the collector of the district in which the alcohol was denatured and the other to the collector of the district in which the manufacturing plant is located.

MANUFACTURER'S ALCOHOL RECORD.

Sec. 99. The manufacturer must keep a record in which he shall enter on the "Received" side the date upon which he receives any denatured alcohol on his premises, the number of packages received and the name and address of the distiller, the district in which denatured, the name of the officer who gauged the alcohol, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, the number of wine gallons, and the number of proof gallons.

These entries must be made at the time the denatured alcohol is received in the storeroom and before any of it is withdrawn from the packages or is used in manufacture.

On the "Disposed of" side of the record must be entered the denatured alcohol used in manufacture. The entries must show the date upon which any packages of denatured alcohol are broken for use in manufacture, the number of packages, the name and address of the distiller who denatured the alcohol, the name of the officer who affixed the denatured alcohol stamp, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, the wine gallons, and the proof-gallons contents of the packages.

This record must have spaces and columns in which can be entered the number of packages and the quantity in wine and proof gallons of unbroken packages brought over in stock from previous month, of broken packages brought over from previous month, total of such packages brought over, of packages received during the month, of packages used during the month, of unbroken packages on hand at the end of the month, of broken packages on hand at the close of the month, and the total on hand at the end of the month.

TRANSCRIPT TO BE MADE OF RECORD.

Sec. 100. A transcript of this record must be prepared, sworn to, and forwarded to the collector of internal revenue of the district for each month before the tenth day of the following month.

The affidavit above referred to must be in the following form:

STATE OF ———,

COUNTY OF ———.

On this day personally appeared before me ——— ———, duly designated custodian of the storeroom for specially denatured alcohol No. —— of the ——— district of ———, of denatured alcohol received and to be used at the manufacturing establishment of ——— ———, manufacturer of ———, at ———, in the county of ———, State of ———, and on oath states that the above is a true and correct statement on the debit side of the specially denatured alcohol received in said storeroom, and on the credit side, of the specially denatured alcohol charged off for use in manufacturing ——— at said manufacturing establishment, and that all of the alcohol delivered from said storeroom was delivered in exactly the same condition as when received at said storeroom and was delivered for use in manufacturing ——— and was so used.

——— ———, *Custodian* ———.

Subscribed and sworn to before me this —— day of ———, 190—.

——— ———.

This affidavit must be made by the person who has the custody of the storeroom, whether it be the manufacturer himself or one of his employees.

MANUFACTURER'S RECORD OF ALCOHOL USED AND ARTICLES PRODUCED.

Sec. 101. The manufacturer must also keep a book in which shall be entered the quantity of goods produced and finished each month and in which specially denatured alcohol was used, and at the close of business each month and before the 10th of the following month the manufacturer must make and forward to the collector of internal revenue a transcript of this record and must affix an affidavit in the following form:

STATE OF ———,

COUNTY OF ———.

On this day personally appeared before me ——— ———, who on oath states that the above is a true, correct, and complete statement of the goods manufactured during the month last past and in the manufacture of which denatured alcohol was used at the place of business of ———, located at ———, in the county of ———, State of ———.

———————.

Subscribed and sworn to before me this —— day of ———, 190—

———————.

This affidavit must be made by the manufacturer himself, the manager of the business, superintendent, bookkeeper, or other person who has knowledge of the facts.

Care should be taken to see that both of the above-prescribed records and the reports made therefrom are in every respect true and correct. Failure to keep these records correctly and to make correct reports from them promptly as prescribed by these regulations is a breach of the bond required of the manufacturer and he incurs the liabilities growing out of such breach.

The affdavits may be made before any revenue officer authorized under the law to administer oaths. Such officer is not permitted to make any charge for such service. In the event it is not practicable to have these returns sworn to before a revenue officer they may be sworn to before any officer authorized by State or Federal law to administer oaths.

CUSTODIAN OF STOREROOM TO BE DESIGNATED.

Sec. 102. The manufacturer must either be the custodian in person of the storeroom for specially denatured alcohol or he must designate some one of his employees to be the custodian. The manufacturer must notify the collector of the district of the person who has been designated as the custodian of the storeroom, and if for any reason a change is made the collector must be promptly notified.

No one must be permitted to go into the storeroom in the absence of the custodian. The door of the storeroom must be provided with suitable lock for securely fastening it, and the custodian must carry the key to the lock. It will be his duty, together with the manufacturer (provided he is an employee and not the manufacturer), to see that none of the denatured alcohol brought upon the premises is diverted from the use for which it was denatured. He must keep the denatured alcohol storeroom record herein provided for and must prepare, sign, and swear to the returns.

If the manufacturer is a corporation the custodian of the storeroom for specially denatured alcohol and the person who is to keep the record of denatured alcohol used and articles manufactured and make the returns herein prescribed, must be named by the board of directors or other governing power and a certified copy of the minutes of the meeting at which said persons were so designated must be forwarded to the collector of the district.

MANAGER TO MAKE AFFIDAVIT.

Sec. 103. The manufacturer or the manager of the business, provided the manufacturer is a corporation, must, in the event some one other than himself keeps one or both of the records and makes one or both of the returns herein prescribed, make the following affidavit to such of the returns as he does not personally prepare and swear to.

STATE OF ———,

COUNTY OF ———.

I, ——— ———, state on oath that I am ——— ——— of the business of ———, and that from my knowledge of said business gained as such ———, I verily believe the above stated accounts are correct and that the above affidavit of ——— ——— is in every particular true.

——— ———,

——— ———

Subscribed and sworn to before me this —— day of ———, 190—.

COLLECTOR TO KEEP RECORD OF MANUFACTURER'S OPERATIONS.

Sec. 104. The collectors of internal revenue of the several districts shall keep in a record, specially prepared for the purpose, an account of each manufacturer in the district using specially denatured alcohol.

Said record shall be made up from the reports of officer showing the shipment of denatured alcohol to the manufacturer, and the reports of the manufacturer on the proper forms.

Said record must show the date upon which any alcohol was shipped from the denaturing bonded warehouse, the date it was received by the manufacturer, the name of the distiller, the location and number of the denaturing bonded warehouse at which it was denatured, the number of packages in the lot, the serial numbers of such packages, the serial numbers of the denatured alcohol stamps, the wine gallons, and the proof gallons.

Said record must also show the number of packages, serial numbers of such packages, serial numbers of the stamps and quality of alcohol charged off for use in the manufacturing business, and the quantity used in such business. It must also show the quantity of the manufactured article in proper denominations produced each month. There must also be columns and spaces in which to enter the quantity of alcohol on hand in unbroken packages at the beginning of the month, the quantity in broken packages, the quantity received during the month, the quantity used in the business during the month, the quantity on hand in broken packages at the close of the month, the quantity on hand in unbroken packages, and the total quantity on hand.

ALCOHOL TO BE USED AS RECEIVED.

Sec. 105. Specially denatured alcohol must be used in the manufacture of the products exactly as stated in the manufacturer's application and in the collector's permit, and it can not be used in any other manner, and manufacturers using such alcohol must complete the work of manufacture of the products specified in their notice and bond on the premises upon which they are authorized by their permit to use alcohol.

MANUFACTURER QUITTING BUSINESS MAY DISPOSE OF ALCOHOL TO OTHER MANUFACTURER.

Sec. 106. In the event any manufacturer using specially denatured alcohol for any reason quits the business of manufacturing the commodities authorized by his permit and there remains on hand in his storeroom a quantity of specially denatured alcohol, he may dispose of such alcohol to another manufacturer in the same class of business provided he gives notice to the collector of internal revenue. When such notice is given, a deputy collector or other officer will visit the manufacturer's place of business and check the alcohol on hand against the manufacturer's record. If the quantity on hand is found to agree with the manufacturer's record and the alcohol is in the same condition as it was when denatured, the officer will report to the collector, who will issue a permit authorizing the transfer of the denatured alcohol to the premises of the manufactuer to whom the alcohol has been disposed of. The purchaser must be a regularly qualified manufacturer and must be authorized to use alcohol specially denatured in the manner and under the formula under which the alcohol transferred was denatured.

PROVISIONS APPLICABLE TO MANUFACTURERS USING EITHER SPECIALLY OR GENERALLY DENATURED ALCOHOL.

Sec. 107. Under no circumstances will denaturers, manufacturers, or dealers, or any other persons, in any manner treat either specially or completely denatured alcohol by adding anything to it or taking anything from it until it is ready for the use for which it is to be employed. It must go into manufacture or consumption in exactly the same condition that it was when it left the denaturer. Diluting completely denatured alcohol will be held to be such manipulation as is forbidden by law.

Sec. 108. Manufacturers using either specially or completely denatured alcohol must store it in the storeroom set apart for that purpose, the place for deposit named in the bond and application, and nowhere else. Likewise they must deposit recovered alcohol in said storeroom as fast as it is recovered. It will be held to be a breach of the bond and a violation of the law if any alcohol of any kind, character, or description should be found stored at any other place on the premises.

COLLECTOR TO BE NOTIFIED OF CHANGE IN PLANT.

Sec. 109. If there are any material changes in the manufacturing establishments at which either specially or completely denatured alcohol (where permit is required) is used, either in the plant or in the methods of manufacture, or if there is any change in the ownership of the establishment, new application must at once be filed, new bond given (if bond is necessary), and new permit granted by the collector.

Sec. 110. Persons who use alcohol denatured in any manner except as is expressly authorized by the law will be held to be liable for double the amount of the tax on all the alcohol so used, in addition to the penalties, civil and criminal, expressly provided by the act of June 7, 1906.

PART IV.

ALCOHOL RECOVERED, RESTORED, AND REDENATURED.

SEC. 111. Section 2 of the denatured alcohol law provides:

> That manufacturers employing processes in which alcohol used free of tax under the provisions of this act is expressed or evaporated from the articles manufactured shall be permitted to recover such alcohol and to have such alcohol restored to a condition suitable solely for reuse in manufacturing processes under such regulations as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, shall prescribe.

ALCOHOL TO BE RESTORED ON PREMISES WHERE USED OR IN A RESTORING PLANT.

SEC. 112. The work of recovering alcohol and restoring it to conditions suitable for reuse in manufacturing processes must be done on the premises on which said alcohol was originally used or at a duly authorized restoring plant, and it must be reused in the same manufacturing establishment in which it was originally used (except as provided in Part V. of these Regulations).

STILL MAY BE USED.

SEC. 113. If in restoring alcohol to a condition suitable for reuse a still is necessary, the manufacturer may set up on his premises such still and any other apparatus that may be necessary for use in connection with or independent of the still in the work of recovering such alcohol. The still must be registered in the same manner in which the law and regulations require that all stills set up be registered. It can not be used for any other purpose than to recover by redistilling alcohol that has been withdrawn from bond free of tax for denaturing purposes, denatured, and then used by the manufacturer.

APPLICATION TO BE USED.

Sec. 114. A manufacturer desiring to recover and reuse such alcohol must in his application for permit to use denatured alcohol in his business, in addition to the statements required to be made in said application, state fully the manner in which he intends to recover alcohol, the condition as to proof, purity, etc., of the alcohol when it is recovered, the percentage of alcohol used in said business which he proposes to recover, and the estimated quantity in proof gallons of alcohol he expects to recover during the year. If it is necessary before redenaturing said alcohol to redistill or otherwise treat it in order to restore it to a condition suitable as to proof and purity for use in the particular manufacture for which it is intended, the process must be explained, and if a still is used the capacity of the still must be set out in full and the other apparatus used in connection with the still must be described.

The application for permit must, in addition to the form heretofore prescribed (see Sec. 83), contain the following:

Said ——— ——— desires to recover alcohol used in said business in the following manner, - ——— The condition of said alcohol when recovered as to purity and proof will be ———; the percentage of alcohol used in said business which said ——— ——— expects to recover is ———, and the total quantity —he— expect— to recover during the year beginning with July 1, 190--, is ——— proof gallons. In the process of restoring alcohol to a condition suitable for use, the following apparatus will be used, ——— and the said ——— ——— desires to redenature the alcohol so recovered or restored, provided redenaturation is necessary, in the storeroom for denatured alcohol on said premises in the following manner ———.

The bond prescribed in the case of manufacturers using specially denatured alcohol (see Sec. 88) must, in addition to the provisions in the form set out, contain the following additional provisions:

And whereas the said —— —— proposes to recover alcohol used in said manufacture in the following manner ——, said alcohol when so recovered to be in the following condition as to proof, etc., ——, and proposes to restore said alcohol to a condition suitable for reuse in the following manner ——, and proposes to redenature said alcohol so recovered and restored, provided redenaturation is necessary, before reusing same in the storeroom for denatured alcohol on said premises.

Now therefore if the said —— —— shall remove all of said alcohol so recovered and restored to a condition suitable for reuse to —— storeroom for denatured alcohol on said premises as soon as it is so recovered and restored, shall safely keep said alcohol in said storeroom until it shall have been redenatured, provided redenaturation is necessary, shall pay double the tax of one dollar and ten cents on each proof gallon of all alcohol recovered and reused in any manner without having first been redenatured, and shall fully, promptly, and faithfully comply with all the law and regulations relating to the recovering and restoring to a condition fit for reuse and the redenaturing of alcohol that has been withdrawn from bond without the payment of the tax.

BOND TO BE EXECUTED BY MANUFACTURER USING COMPLETELY DENATURED ALCOHOL.

Sec. 115. No manufacturer's transportation and storage bond being required of a manufacturer using in his business completely denatured alcohol, in case such manufacturer desires to recover and redenature such alcohol so that it may be reused he must execute a bond containing the provisions of the two above prescribed paragraphs. The penal sum of said bond shall be double the tax on the alcohol it is estimated the manufacturer will recover and redenature in thirty days. Said bond must be executed in duplicate and must be approved by the collector of the district in the same manner as manufacturers' bonds heretofore prescribed. He must also provide storeroom for the denatured alcohol used by him and must designate some one to act as custodian thereof, and he must keep such records and make such returns as are required in case of manufacturers using specially denatured alcohol.

The permit issued to the manufacturer by the collector must contain, in addition to what is contained in the form heretofore prescribed, the following:

> And the said —— —— is hereby further authorized and permission is given —— to recover and restore to a condition suitable for use in said manufacture alcohol in the following manner —— ——. Said alcohol must be stored in the denatured-alcohol storeroom on said manufacturer's premises and must be redenatured in said storeroom before it is reused, provided redenaturation is necessary.

ALCOHOL TO BE STORED IN STOREROOM AS RECOVERED.

Sec. 116. The manufacturer must draw off the alcohol as it is recovered into packages and must immediately store it in exactly the same condition as it is when recovered in the storeroom for denatured alcohol, and it shall thereafter be in charge of the custodian of said warehouse. Alcohol recovered at such establishment and placed in the warehouse for denatured alcohol will not be redistilled or otherwise treated except in the presence of the proper officer.

STILL USED FOR RECOVERING ALCOHOL ONLY, ETC.

Sec. 117. The still employed in redistillation will not be used for any purpose except to redistill alcohol for redenaturation, and it will not be used except in the presence of the proper officer. When the still is not being used the furnace door or cocks controlling the steam connections will be securely locked and the collector will keep the keys to said locks in his possession.

APPLICATION TO HAVE ALCOHOL RESTORED AND REDENATURED.

Sec. 118. At such intervals as the necessities of the business may demand, and when the manufacturer has a sufficient quantity of recovered alcohol on hand to justify the sending of an officer to his place of business, he may make application to the collector of the district for an officer to be detailed to supervise the work of redistilling or otherwise treating the recovered alcohol and the redenaturing of it. Such application will be in the following form:

——— ———,

Collector ——— District of ———.

You are hereby notified that there is stored in the storeroom for denatured alcohol on the manufacturing premises of ——— gallons of alcohol, ——— proof, which was withdrawn from bond, free of tax, and denatured, and which was used in the process of manufacturing ——— and recovered at said place. Request is hereby made that an officer be sent to said place of business to supervise the work of restoring and redenaturing said alcohol.

——— ———,

Manufacturer.

COLLECTOR TO DETAIL OFFICER TO VISIT MANUFACTURING PLANT.

Sec. 119. Upon receipt of the manufacturer's notice the collector will detail an officer to proceed to the manufacturing premises in question and supervise the work of restoring to suitable condition and redenaturing the alcohol mentioned in the notice. The instructions of the collector shall be in the following form:

——— ———,

——— ———.

——— ———, manufacturer of ———, and proprietor of storeroom for the denatured alcohol No. —, in this district, located at ———, has notified me that ——— ——— ha— stored in ——— storeroom ——— gallons of alcohol of ——— proof, recovered in process of manufacture, and ——— desire ——— to have said alcohol restored to a condition suitable for use in the manufacture of ——— and redenatured (if necessary) in the following manner ——— at said storeroom.

You are hereby instructed to proceed at once to said manufacturing establishment and supervise the work of restoring and redenaturing said alcohol in the manner indicated. You will gauge, mark, stamp, and brand the packages of redenatured alcohol and will make due return of same.

———— ————,
Collector ———— *District of* ————

OFFICER TO VISIT MANUFACTURING ESTABLISHMENT.

Sec. 120. Upon receipt of these instructions the officer will proceed at once to the manufacturing establishment, and will supervise the work of restoring and redenaturing the alcohol in accordance with the regulations.

The agents to be used in redenaturing must be brought into the storeroom and must be inspected by the officer immediately upon his arrival there. He must take samples of each denaturant and forward them, properly marked and labeled, to the nearest laboratory. If the denaturants are in two or more packages he must secure an equal part from each package so that the sample will be a representative one.

The packages or tanks containing the denaturants must be sealed and must remain sealed until the officer receives the report upon the samples sent.

Sec. 121. If the report is favorable to the samples, the officer in charge of the storeroom may, after the receipt of the report, permit the denaturing agents to be used in accordance with the general or special specifications, as the case may be, in redenaturing alcohol at said storeroom.

If the report is unfavorable the proposed denaturants shall at once be removed from the storeroom by the manufacturer.

While the officer is at the manufacturing establishment supervising the work of restoring and redenaturing the alcohol, the storeroom will be in his custody and he must carry the key to it.

RESTORING, REDENATURING, AND GAUGING THE ALCOHOL.

Sec. 122. The process of restoring the alcohol to a condition suitable for use will be carried on in the presence and under the supervision of the officer. If in the process of restoring the alcohol to a condition suitable for reuse it is necessary to remove it from the storeroom, it will be returned to said storeroom as rapidly as it is restored and drawn off into suitable packages. The officer will, in having the packages filled with the restored alcohol, leave a wantage equal in volume to the denaturants to be added. He will ascertain by weight the wine and proof gallons in each package before any denaturant has been added. He will then cause the denaturants to be added to the package and will gauge, mark, stamp, and brand the package of redenatured alcohol.

The same kind of packages and stamps prescribed by these regulations for alcohol denatured at denaturing bonded warehouses will be used for alcohol redenatured at storerooms for denatured alcohol. Packages of redenatured alcohol shall be numbered serially, beginning with number one, at each storeroom.

PACKAGES TO BE MARKED, STAMPED, AND BRANDED.

Sec. 123. The officer shall put the following marks, stamps, etc., on the package when he gauges it:

On the stamp head he shall stencil the following:

The serial number of the package, the date of redenaturation and gauge, the wine gallons, proof and proof gallons, the name of the manufacturer and the number of the storeroom, the State and the district, the name and title of the officer, and the number of the denatured alcohol stamp affixed to the package. The words "Redenatured alcohol" must be placed upon each head of the package.

The stamp must be affixed and signed by the officer.

The stamps will be furnished by the collector as they are needed, and the officer must take the books of unused stamps with him when he has finished the work of restoring and redenaturing alcohol and return them to the collector.

OFFICER TO MAKE RETURN AND KEEP RECORD.

Sec. 124. Having gauged and marked the several packages of redenatured alcohol the officer will make return of such gauge, wherein he will show in proper columns in detail the capacity of each package, its gross weight, tare, net weight, indication, temperature, net wine gallons contents, proof and proof gallons contents before the denaturants were added, the net wine, proof and proof gallons contents after the denaturants were added, apparent proof, apparent proof gallons contents, the serial number of the package, and the serial number of the denatured alcohol stamp affixed to it.

Sec. 125. The officer shall keep a record in which he shall enter in proper columns and spaces in detail on the debit side the quantity of recovered alcohol in wine and proof gallons found in the storeroom when he arrived at the establishment, the quantity in wine and proof gallons of alcohol restored each day, the manner in which said alcohol was restored, the quantity in wine and (if possible) proof gallons of the several denaturants used each day, the kind of denaturants used, and the numbers of denaturant samples sent to the laboratory.

On the credit side shall be entered in the proper columns the date upon which any alcohol is redenatured, the number of packages, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps on said packages, and the wine and proof gallons.

OFFICER TO MAKE REPORT OF OPERATIONS AT STOREROOM.

Sec. 126. At the end of each month, or as soon as the work of restoring the alcohol to suitable condition and the redenaturing of it is completed, the officer must make a transcript in duplicate from this record and forward it to the collector.

MANUFACTURER TO KEEP RECORD.

Sec. 127. The manufacturer must keep a record in which he shall enter daily in proper spaces and columns the quantity in wine and proof gallons of alcohol recovered by him and placed in storeroom, the quantity of denaturants placed in said storeroom for redenaturing purposes, and the quantity of alcohol, in wine and proof gallons, restored to a condition suitable for use, and the quantity of each denaturant used.

He shall also enter in said record daily the quantity of alcohol redenatured in his storeroom, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, and the wine and proof gallons of the redenatured alcohol.

MANUFACTURER TO MAKE TRANSCRIPT AND REPORT.

Sec. 128. He must prepare a transcript of this record at the end of the month; and before the 10th day of the following month he must swear to same and forward it to the collector of internal revenue. The affidavits to this report must be made by the custodian of the storeroom and the manager of the business and must be in the following form:

State of ———,
County of ———:

I, ——— ———, state on oath that I am custodian of the storeroom for denatured alcohol, No. ——, at the manufacturing establishment of ——— ———, manufacturers of ——— at ———, in the county of ———, State of ———, and that the above is a true, correct, and complete statement of the alcohol withdrawn from bond, free of tax, and denatured at denaturing bonded warehouse, recovered in said manufacturing establishment, restored to condition suitable for reuse at said place and redenatured in said storeroom for denatured alcohol (or that such redenaturation was not found necessary), and that no alcohol, which was recovered and restored at said place, was used in any manner until after it had been redenatured, nor was any redenatured alcohol used in any manner except in the manufacture of ——— at said place.

——— ———,
Custodian Storeroom No. ——.

I, ——— ———, state on oath that I am ——— ———, of the above-described business, and from my knowledge of the business I believe the above report of business done to be true, correct, and complete, and the statements contained in the above affidavit of ——— ———, custodian at said storeroom, to be in every respect true and correct.

——— ———,
———.

The above two affidavits were subscribed and sworn to before me this —— day of ———, 190—.

——— ———.

MANUFACTURER TO MAKE ENTRY IN RECORD OF ALCOHOL RECEIVED AND DISPOSED OF, ETC.

Sec. 129. The manufacturer must also enter on his record of denatured alcohol received and disposed of the packages of alcohol redenatured at said storeroom. On the "Received" side of said record must be shown the date upon which the alcohol was received from redenaturation. The alcohol must be treated in the same manner on said record as it was when received originally.

In the summary on said record the quantity of alcohol received from redenaturation and reused must be shown in items separate from the denatured alcohol coming into the stock originally from dealers and denaturers.

COLLECTOR TO KEEP ACCOUNT WITH MANUFACTURER OF ALCOHOL RESTORED.

Sec. 130. The collector must keep an account with each manufacturer who recovers, restores, and redenatures alcohol. This record must be made from the reports of the chemist, officer in charge of the storeroom, and manufacturer. It must show the quantity of alcohol recovered and deposited in storeroom each day, the quantity restored to a condition suitable for reuse, the quantity and kind of denaturants used in denaturing said alcohol, the name of the officer supervising the restoring of and redenaturing of said alcohol, the number of packages and the serial number of same, and the quantity in wine and proof gallons of alcohol redenatured, gauged, and delivered to the manufacturer for reuse.

ALCOHOL NOT TO BE REDENATURED UNLESS NECESSARY.

Sec. 131. Manufacturers who recover alcohol will not be required to have said alcohol redenatured if it retains a sufficient quantity of the original denaturants to prevent its use as a beverage. If necessary, this may be determined by the chemical examination of samples taken for this purpose and forwarded to the nearest laboratory. In the event it is not necessary to redenature the alcohol the manufacturer must deposit it in his storeroom in suitable packages and make application to the collector of internal revenue to have it regauged and restamped. The collector will detail an officer to visit the storeroom and regauge and restamp the alcohol. When it has been regauged and restamped the alcohol will be taken up on proper records by the officer and the manufacturer, and will appear on the monthly reports in the same manner as though it had been redenatured. The officer making the regauge will make a report in the same manner as is required when alcohol is redenatured on the manufacturer's premises, except that the report will not show that the goods are redenatured.

PART V.

RESTORING AND REDENATURING PLANTS.

SEC. 132. Centrally located plants may be established for the purpose of restoring to a condition suitable for re-use and for redenaturing, if necessary, alcohol recovered by manufacturers; these plants to be located at such places as the Commissioner of Internal Revenue may deem necessary.

WAREHOUSE: HOW CONSTRUCTED.

SEC. 133. A warehouse constructed in the manner in which distillery warehouses are constructed must be provided. This warehouse to be used for the purpose of storing recovered denatured alcohol received from manufacturing establishments. Either an apartment in this warehouse or a separate warehouse may be provided in which to redenature and store the restored alcohol. This apartment or separate warehouse, as the case may be, must be constructed in the same manner as denaturing bonded warehouses heretofore described. It must be supplied with mixing tanks, and a room to be used as a denaturing material room must be provided. The apartment used as a denaturing bonded warehouse must be separated from the apartment used as a storage room for the recovered alcohol received from manufacturers, and there must be no openings or doors between the two apartments.

The denaturing material room must be constructed in the same manner as similar rooms are constructed at denaturing bonded warehouses, and all of the appliances required at denaturing bonded warehouses must be supplied.

CISTERN ROOM TO BE PROVIDED.

SEC. 134. A cistern room constructed in the same manner as are cistern rooms at registered distilleries must be provided. In the process of restoring the recovered alcohol by redistillation, it must be received into the cisterns direct from the worm or condenser in the same manner as distilled spirits are received into the cisterns at registered distilleries.

The cisterns and cistern room must be supplied with the same kind of locks as are required for similar rooms at registered distilleries.

Sec. 135. When the restoring and redenaturing plant is in operation it must be under the supervision and control of a storekeeper-gauger or other officer designated by the collector of internal revenue.

This officer shall carry the key to the warehouse or warehouses used in connection with the plant and the cistern and cistern rooms. When operations at the plant are suspended for the day he shall lock the steam valves controlling the supply of steam to the several parts of the plant, and such other appliances as will prevent the plant from being operated during his absence. Under no circumstances is he to permit any work to go on during his absence, and he shall exercise the same kind of surveillance over the plant as is exercised at registered distilleries.

APPLICATION TO BE MADE TO COLLECTOR.

Sec. 136. Any person desiring to establish a plant at which denatured alcohol recovered at a manufacturing establishment may be restored and redenatured shall make application to the collector of internal revenue in the district in which such plant is to be located.

In this application he shall state the exact location of said plant. He shall describe all of the buildings located on the premises. In this description he shall give the size of each building, the materials of which it is constructed, and their location with reference to each other. He shall describe all of the apparatus intended to be used in the work of restoring alcohol.

If one or more stills are used he shall describe each still accurately, giving the capacity of each, together with all of the connections and other apparatus used therewith. He shall describe the cisterns, cistern rooms, warehouses, or tanks constituting a part of the plant, giving the capacity of each cistern or tank in gallons.

The application may be in the following form:

To Collector of Internal Revenue,
——— *District of* ———

SIR: Notice is hereby given that I have erected for the purpose of restoring denatured alcohol and redenaturing it a plant located at ———, State of ———, described as follows: ———

[Here given description of the plant, together with the cistern cistern room, still or stills, warehouse, etc., as required above.]

and you are hereby requested to cause such proposed restoring and redenaturing plant to be inspected with a view of determining whether or not it is constructed in compliance with the law and regulations

——— ———,
Proprietor.

A diagram upon which is shown the entire plant with all the buildings located on the premises must be submitted with this application.

Upon receipt of the application the collector will, either himself, or by one of his deputies, visit and inspect the premises. He will determine whether or not the plant is constructed in accordance with the regulations, and whether or not the statements made in the application and the representations made on the diagram are true.

If he finds that the statements are correct and that the plant is constructed in accordance with the regulations, he will so indorse upon the application, and the collector will forward same to the Commissioner of Internal Revenue.

If the Commissioner is of the opinion that the establishment of the plant [illegible] necessary, and that it is constructed in accordance with the law and regulations, he will approve it and will so advise the collector.

BOND FOR RESTORING AND REDENATURING PLANT.

Sec. 137. Upon receipt of notice from the Commissioner of Internal Revenue that the restoring and redenaturing plant has been approved, the collector shall notify the proprietor of the plant of such approval, and thereafter he may receive upon his premises, restore, and redenature alcohol, provided, he shall first make a bond in the following form:

Know all men by these presents, That ——— ———, of ———, as principal, and ——— ———, of ———, as sureties, are held and firmly bound unto the United States of America, in the sum of ——— dollars, for the payment whereof to the United States we bind ourselves, our heirs, executors, and administrators, jointly and severally, firmly by these presents.

The condition of this obligation is such that whereas the above bounden principal has established a plant for restoring and redenaturing alcohol, located at ———, and whereas said plant has been approved by the Commissioner of Internal Revenue and the said principal has been authorized to receive upon his premises and store in his warehouse alcohol withdrawn from bond, free of tax, denatured, used at manufacturing establishments and recovered in the process of manufacture, and has been authorized to restore such alcohol so received to a condition suitable for reuse in manufacturing processes, and has been authorized to redenature such alcohol at his redenaturing warehouse located at said plant. Now, if the said ——— ——— shall, in the operation of his restoring and redenaturing plant, bring into the warehouse specially set aside for that purpose, all of the recovered alcohol consigned to him by manufacturers wherever located, shall safely store in said warehouse all of said alcohol so rece[illegible], shall restore all of said alcohol to a condition suitable for reuse i[illegible]anufacturing processes and redenature it in his redenaturing apartment or warehouse, in the manner prescribed by regulations; and if he shall pay the tax of one dollar and ten cents per proof gallon upon all the alcohol that may be consigned to him by any manufacturer and not properly stored in said warehouse, or stored in said warehouse and not duly restored, or duly stored and restored and not duly redenatured by him, and if he shall in all respects comply with all of the requirements and provisions of the law and regulations in relation to storing, restoring, redenaturing, and disposing of said alcohol, then this obligation is to be null and void, otherwise to remain in full force and effect.

It is the intent and purpose of this obligation that it shall operate as a transportation, warehousing, restoring, and redenaturing bond, and that liability under it shall attach the moment any recovered alcohol is put in transit by a manufacturer to the principal herein; while it is in transit to him; after it has been deposited in the warehouse located on his restoring and redenaturing plant, while it is in process of being restored; after it has been deposited in his redenaturing apartment or warehouse, while it is in process of redenaturation, after it has been redenatured, and while it is in transit to any manufacturer to whom it may be consigned.

——— ——— [SEAL.]
——— ——— [SEAL.]
——— ———. [SEAL.]

Signed and sealed in the presence of—

——— ———.

PENAL SUM OF BOND.

SEC. 138. The bond required of the proprietor of a restoring and redenaturing plant shall be in the penal sum of not less than the tax on the alcohol it is estimated will be restored and redenatured thereat in thirty days, and in no event shall it be less than five thousand dollars or more than one hundred thousand dollars. The sureties may be either personal sureties or a corporate surety duly authorized to make bonds under the existing laws.

QUANTITY OF ALCOHOL TO BE RETURNED TO MANUFACTURER.

SEC. 139. Alcohol restored and redenatured at a plant established for that purpose may be restored to a condition suitable for reuse in manufacturing processes only. Alcohol recovered by any manufacturer using either specially or completely denatured alcohol may be restored and redenatured in accordance with the regulations herein prescribed, but in each case the manufacturer sending alcohol to such plant to be restored and redenatured must receive back from such plant a quantity of alcohol equal to that sent to the plant to be restored and redenatured, less any reduction in quantity attending the necessary process of restoration. In no event shall a manufacturer receive any greater quantity of alcohol from a restoring and redenaturing plant than is sent to such plant by him, allowance being made, of course, for the denaturants added; and in no event shall alcohol redenatured at a restoring and redenaturing plant be delivered or disposed of for reuse to anyone except a manufacturer who had delivered recovered alcohol to such plant.

NO OTHER BUSINESS TO BE CARRIED ON.

Sec. 140. No business can be carried on on the premises of a restoring and redenaturing plant except such business as is incident to the work of receiving, depositing, restoring, and redenaturing alcohol received there, and no tax-paid alcohol can be received on these premises.

Sec. 141. The premises of all restoring and redenaturing plants shall at all times be open to the inspection of duly authorized internal revenue officers, and they shall have the right to observe the processes and methods employed, and take such samples of the product of the plant as in their judgment may be necessary.

PLANT TO BE SECURED ON SUSPENSION.

Sec. 142. When the plant is suspended the officer in charge must securely lock all valves and cocks controlling the supply of steam, and the furnace doors; likewise he must securely lock the cistern rooms and warehouses connected with the plant and deliver the keys to the collector of the district; and when the plant suspends operations it must be placed in such condition by the officer that it can not be operated during his absence, or until notice has been given to the collector by the proprietor of his intention to resume work.

When the proprietor of the restoring and redenaturing plant desires to suspend operations, he shall give the collector of internal revenue notice of such intention; and when he desires to resume operations he shall likewise give notice, and the collector will thereupon assign an officer to the establishment who shall have custody and control of it during the period of operations.

PROPRIETOR OF RESTORING PLANT TO OWN REAL ESTATE.

Sec. 143. In his application for permit to operate a restoring and redenaturing plant the proprietor must state the name of the person or persons holding the fee-simple title to the real estate upon which the plant is located. In the event the title is not in the proprietor of the plant, he must secure the consent of the owners of such fee simple title in the same manner as is required in the case of registered distilleries.

MANUFACTURER TO KEEP RECORD AND SEND NOTICE OF SHIPMENT.

Sec. 144. A manufacturer using denatured alcohol and recovering it in process of manufacture, and desiring to have such alcohol restored to a condition suitable for reuse in manufacture at a restoring and redenaturing plant, must deposit such alcohol as it is recovered in the designated storeroom on his manufacturing premises, in the same manner as required of manufacturers who restore alcohol on their own premises.

He must keep a record, in which he shall enter the quantity of alcohol in wine and proof gallons recovered each day and stored in his storeroom. At such times as he may desire, he may ship such recovered alcohol to a restoring and redenaturing plant, but before it leaves his storeroom he must put it into suitable packages, and upon the head of each package he must place the following marks:

Denatured alcohol recovered at the manufacturing establishment of ——— ———, storeroom No ——, located at ———, in the district of ———, ——— wine gallons, ——— proof gallons, serial No. ——.

He must number these packages serially, beginning with No. 1.

Upon the credit side of his record he shall enter the date upon which he sends any recovered alcohol to the restoring and redenaturing plant, the name of the proprietor of the plant to which it is sent, the number of packages, the serial numbers of the packages, and the wine and proof gallons.

NOTICE TO BE SENT TO COLLECTOR.

Sec. 145. Upon the date upon which he places in transit any recovered alcohol he must prepare a notice, in which he shall state the number of packages, the serial numbers of the packages, the wine and proof gallons, and the name of the restoring and redenaturing plant to which the recovered alcohol is sent.

This notice must be in triplicate, provided the restoring and redenaturing plant is located in one district and the manufacturing establishment is located in another. If they are both in the same collection district, then it may be prepared in duplicate. One copy of the notice is to be sent to the collector of the district in which the manufacturing plant is located, another copy to the collector of the district in which the restoring and redenaturing plant is located (provided it is in another district), and the remaining copy to the officer in charge of the restoring and redenaturing plant.

As soon as the recovered alcohol reaches the restoring and redenaturing plant the proprietor of the establishment must deposit it in the warehouse located on the premises, and it must remain in this warehouse until it is ready to be redistilled and restored.

RECORD TO BE KEPT BY PROPRIETOR OF RESTORING PLANT.

Sec. 146. The proprietor of the restoring and redenaturing plant must keep a record in which he shall enter the date upon which he receives any recovered alcohol. In this record he must give the name and address of the manufacturer from whom the alcohol was received, the number of packages, the serial numbers of the packages, the wine and proof gallons.

Upon the credit side he shall enter the date upon which he sends any redenatured alcohol to the manufacturer, the name of the manufacturer, the number of packages, the serial numbers of the packages, the name of the officer inspecting the packages, the serial numbers of the stamps, and the wine and proof gallons.

At the end of the month and before the 10th day of the ensuing month he must prepare and forward to the collector of internal revenue a transcript of this record. Said transcript will constitute his return for the month and must be duly sworn to.

OFFICER TO KEEP RECORDS AND MAKE RETURNS.

Sec. 147. The officer in charge of the restoring and redenaturing plant must keep a record in which he shall enter the date upon which any recovered alcohol is deposited in the warehouse, the name and address of the persons from whom received, the number of packages, the serial numbers of the packages, and the wine and proof gallons.

Upon the credit side of this record he shall enter the date upon which he delivers any alcohol to the proprietor of the plant for restoring purposes, the name and address of the persons from whom the alcohol was received, the number of packages, the serial numbers of the packages, and the wine and proof gallons.

From this record he shall make a report each day to the collector, in which he shall show the number of packages of recovered alcohol entered into the warehouse on that date, the name and address of the persons from whom it was received, the serial numbers of the packages, and the wine and proof gallons.

This report shall also show the quantity of recovered alcohol delivered from the warehouse to the proprietor of the plant for restoring purposes, the name and address of the persons from whom received, the serial numbers of the packages, and the wine and proof gallons.

The above record and report shall be designated as a warehouse record and report. The report shall be made at the close of business on each day. At the end of the month the officer in charge of the plant shall make a monthly report, which shall be a transcript of this record.

RESTORED ALCOHOL TO BE REMOVED FROM CISTERN ROOM TO DENATURING ROOM.

Sec. 148. As fast as the alcohol is restored it shall be drawn off into packages from the cisterns in the cistern room and shall be gauged and transferred to the denaturing warehouse and at once redenatured. These packages shall be numbered serially, beginning with No. 1 for each restoring plant.

REDENATURING WAREHOUSE RECORD.

Sec. 149. The officer in charge of the plant shall keep a record to be known as the denaturing warehouse record, in which he shall enter each day the number of wine and proof gallons of restored alcohol received from the cistern room and deposited in the denaturing warehouse, the number of packages, and the serial numbers of the packages.

Upon the debit side of this record he shall enter the number of wine and proof gallons of alcohol delivered to the proprietor of the plant each day for redenaturation, the number of packages, and the serial number of each package.

From this record he shall make daily returns showing the quantity of alcohol restored, gauged, and deposited in the denaturing bonded warehouse and delivered to the proprietor of the plant for redenaturation.

He shall likewise keep a record of the denaturants brought upon the premises and deposited in the material room. This record shall be similar to the record kept for the same purpose at denaturing bonded warehouses operated in connection with distilleries.

OFFICER TO KEEP REDENATURATION RECORD.

Sec. 150. The officer shall keep a record of alcohol redenatured, gauged, marked, stamped, branded, and delivered to the proprietor of the restoring and redenaturing plant. This record shall be similar to the record kept in denaturing warehouses operated in connection with distilleries.

The packages of alcohol redenatured at a restoring and redenaturing plant must be numbered serially, beginning with No. 1, and no two packages must have the same number. The packages of alcohol redenatured at restoring and redenaturing plants must be gauged, marked, stamped, and branded in the same manner as such packages are gauged, marked, stamped, and branded at denaturing bonded warehouses operated in connection with distilleries.

Upon the head of the package must be stenciled the name of the proprietor of the restoring and redenaturing plant, the district and State in which it is located, the serial number of the package, the serial number of the stamp, and the wine and proof gallons, and the words "Redenatured alcohol" must be placed thereon in legible letters.

ALCOHOL SENT OUT FROM REDENATURING PLANTS.

Sec. 151. If the alcohol is redenatured by the use of special denaturants, then the same kind of notices as are given to the several collectors in the case of specially denatured alcohol sent out from denaturing bonded warehouses operated in connection with distilleries must be prepared and forwarded to the collector. Likewise, the manufacturer receiving the alcohol must give a notice to the collector of his district similar to that required in a case of specially denatured alcohol received direct from denaturing bonded warehouse. The manufacturer must charge himself on his record with the alcohol received in the same manner as is required in the case of alcohol received direct from denaturing bonded warehouse.

COLLECTORS TO KEEP RECORDS.

Sec. 152. Collectors in whose districts restoring and redenaturing plants are operated shall be provided with records in which shall be kept the account of each plant. In this record shall be entered the quantity in wine and proof gallons of recovered alcohol daily received and deposited in the warehouse at said plant, the number of packages, the serial numbers of the packages, and the names of the manufacturers from whom received.

Said record shall also show the quantity of alcohol in wine and proof gallons delivered to the proprietor of the plant each day to be restored, the names and addresses of the persons from whom received, the number of the packages, and the serial numbers of the packages.

Collectors shall also keep records similar to those kept in case of denaturing bonded warehouses, showing the quantity of alcohol deposited in said redenaturing warehouse, the quantity of denaturants deposited in the material room, the quantity of alcohol and denaturants dumped each day, and the quantity of redenatured alcohol withdrawn from the dump, gauged, and delivered to the denaturer.

Persons desiring information as to the operation of distilleries for the production of alcohol will be furnished with all the laws and regulations controlling upon application made to collectors of internal revenue or to this Office. The several forms herein prescribed will be furnished collectors on requisition; and the Catalogue numbers given such forms will be furnished at an early date.

JOHN W. YERKES,
Commissioner of Internal Revenue.

This September 29, 1906.

Approved:
C. H. KEEP,
Acting Secretary of the Treasury.

INDEX.

- Absolute alcohol, 42
  - preparation of, 43
- Acetal, 318
- Acetaldehyde, 45, 318
- Acetic acid, 45, 234, 235
  - fermentation, 234
- Achroo-dextrin, 28, 29
- Acids, action of, on starch, 30
- Acidity, determination of the, of the yeast mash, 264
  - determination of the, of the fermented mash, 285, 286
  - of the wash, determination of the, 193-195
  - of the wash, determination of the, apparatus for, 194
- After fermentation, the, 268, 269
- Agriculture, benefits of tax free alcohol to, 14-16
  - what tax free alcohol means to, 1, 2
- Agriculturalists, advice to, 16, 17, 18
- Air-cooling, 204
- Air-dried malt, 106, 107
  - diastatic power of, 107
- Air water steeping, 81, 82
- Alcohol, 41-44, 300
  - absolute, 41
  - absolute, preparation of, 43
  - amyl, 44
  - and water, mixtures of, table of specific gravity of and the corresponding per cent by volume and by weight of alcohol, 328
  - as a fuel, 6, 353-372
  - as a fuel, advantages of, 353, 354
  - as a fuel, heat value of, 358
  - boiling point of, 42
  - constitution of, 41
  - denaturants, special, for, 344, 345
  - denatured, 343-352
  - denatured completely, 344
  - denaturing of, 343-352
  - determination of the content of with the hydrometer, 286, 287
  - distillation of, from the fermented mash, 293-327
  - ethyl, 42-44
  - examination of for fusel oil and other impurities, 317, 318
  - for the production of power, 353, 372
  - from corn stalks, 5
  - from fruit, 68
  - from glucose and grape sugar, 160
  - from Jerusalem artichokes, 67
  - from rice, 64
  - from sorghum, 65
  - heating with, 373-390
  - heating with, advantages of, 373, 374
  - heating with, appliances for, 377-390
- Alcohol, heating with, economy of, 374, 375
  - heating with, nature of the fuel, 375-377
  - illumination from, 391-398
  - internal use of, 44
  - lamp, the, 392-397
  - lamp, the, advantages of, 397, 398
  - losses during the distilling process, 287, 288
  - methyl, 41
  - motor, the, 362-372
  - motor, the Marienfelde, 370-372
  - motors, comparative efficiencies of gasolene, kerosene, and, 359-362
  - motors, vaporizers for, 363-370
  - origin of impurities in, 14, 15
  - production, statistics of, 399-407
  - properties of, 42
  - purification of, 317-325
  - raw constituents of, 318
  - rectification and purification of, 317-326
  - regulations and instructions concerning denatured, under the Act of Congress of June 7, 1906, 416-505
  - table, Groening's, amplified by Doemitz, 294
  - table, Groening's, as corrected by Sorel, 295
  - yield of, from the fermentation of the mash, 287-289
  - yield of, from sugar, 41
- Alcoholic fermentation, 204-235
  - fermentation, historical data of, 209-212
  - fermentation periods in, 266-269
  - fermentation of mashes, 204-235
  - liquors, examination of for fusel oil and other impurities, 317-318
- Alcoholometer, the, 286, 326
- Alcoholometry, 42, 286, 326, 327
- Alcohols, boiling points of different, 318
- Aldehyde, 45
  - in alcohol, detection of, 317, 318
- Alkalies, action of upon starch, 29
  - effect of on fermentation, 230
- Allihn's table for determining the dextrose from the reduced copper, 198-200
- Altmann vaporizer, the, 366, 367
- Amides in grain, 88
  - in potatoes, 49
- Amyl alcohol, 45, 318
- Amylobacter, 234
- Amylo-dextrin, 28
- Amylo process, the, 289-292
- Amylomyces, 289
  - Rouxii, 106, 226
  - Rouxii, fermentation with, 289-292
- Amylum, 22-31

Appendix, 411-505
Artichoke, Jerusalem, the, 67
Arts, alcohol in the, 11, 12
Automaton, Ilges' refined spirit, 314, 315
Avenarius Brothers, 126

Bacillus acidificans longissimus, 233
    Fitzianus, 227
    pneumoniae, 227
Bacteria, fermentation exciting, 226, 227
    in the distillery, 232-235
Bacterium prodigiosum, 227
Balling degrees, 185
Barley, 59, 60
    best variety of, for malt preparation, 70-73
    chitting of, 93
    cleansing and sorting of, 75, 76
    composition of, 59
    content of water in, 99
    determination of the proper steeping period for, 80-81
    determination of the suitability of, for malting, 70-73
    germinating power of, 72
    germinating, 88-89
    malt efficacy of, 99
    preparation of malt from, 70-83
    mashing of, 156-159
    starch granules of, 22-24
    steeped, removal of, to the malting floor, 92
    steeped, treatment of, upon the malting floor, 85, 86, 92-94
    steeping of, 77-83
    sterile grains of, 79
    test for the duration of the steeping of, 80-81
    varieties of, 59
    washing machine for, 76
    washing, method of, 75, 76
    weight and volume alterations in, 100
    yield of malt from, 99
Bartel blow-out pipe, the, 129
Bau's method of distinguishing top and bottom yeasts, 223
Bauer's method of yeast preparation, 251
Becher on fermentation, 209
Beer, diseases of, 210
    high fermentation of, 223
    low fermentation, 223
Beet juice, constituents of, 65
    determination of the content of sugar in, 65
    extraction of, by maceration and diffusion, 159
    extraction of, by pressure, 159
    fermentation of, 159
Beet molasses, working of, 159, 160
Beets, sugar, 65
    preparations of mashes from, 159
Belgium, statistics of alcohol production in, 407
    steaming corn in, 133, 134
Benzene, 358, 359
Benzine, 411-415
Bell rectifier, the, 298, 299
Berries, 68
    sugar contents of, 68
Biesdorf steam distribution, the, 137
Blow-out devices of steaming apparatus, 128-131
Bohm's malt milk apparatus, 111
    mash clearing apparatus, 175, 176
    mash mill, 131
    mashing and cooling apparatus, 169-171
Bottom yeast, 223
Brewer's yeast, 223
Brix, introduction of the saccharometer by, 185
Broken couch, the, 93
Buchner's researches on yeast, 211, 212
Buckwheat, 64
Bucheler's method of working concentrated potato mashes, 155
Butyl alcohol, 234, 244
Butyric acid, checking of fermentation by, 230
    fermentation, 234
By-products of fermentation, 44, 45, 288
By-fermentation, loss of alcohol through, 288

Cane sugar, 160
    molasses, working of, 159, 160
Carbohydrates, 21, 25
    determination of the total quantity of, in mash, 195-197
    groups of, 24
Carbon dioxide, 14
Carbonic acid, 14
Carburetors for alcohol motors, 363-370
Carlsberg flask, the, 218
Carrot, gigantic, the, 67
Caustic potash, use of, for the purification of alcohol, 325
Centrifugal apparatus for the preparation of malt and yeast, 110
    mashing apparatus, 162-172
Chamber, yeast, the, 246
Charcoal, apparatus for filtering raw spirit through, 324, 325
    filtering spirit through, 324, 325
    regeneration of, 325
    use of, for the purification of alcohol, 324
Chemicals for purifying raw spirit, 325
Cherries, 68
Chief fermentation, the, 267, 268
Chicory, 67
Chitting of barley, the, 98
Clearing the mash, 173-182
Coal consumption of the distillery, the, 184-185
Coffey's distilling apparatus, 304
Compound distillation, 300
    apparatus for, 300-309
    rectification, and dephlegmation, 300-316
Compressed air, working corn by means of, 143
Concentrated mashing, advantages of, 273, 274
Continuous distilling apparatus, 303-316

Continuous distilling apparatus for the production of raw spirit, 304-309
Cool bed, the, 204
Cooler, movable, the, 253-256
  for fermenting vats, 269-271
  Hesse's, 270
  Kaminski's, 271
Coolers, yeast mash, 255, 256
Cooling apparatus for fermenting vats, 205-207, 269-271
  the mash to the fermenting temperature, 204-208
  with ice, 207, 208
  with ice, quantity required for, 208
Corn, 61, 62
  and potatoes, mashing a mixture of, 144
  composition of, 61
  Indian, 61, 62
  malt, efficacy of, 100
  malt from, 100, 104, 105
  mashing with, 159
  stalks, 5, 67
  starch, determination of, 62
  starch, granules of 23, 24
  transportation of, dangers in the, 62
  working of, at ordinary pressure, 132-135
  working grist, 139-141
  working with sulphurous acid, 134, 135
  working under high pressure, 135-142
  working malted, 143, 144
  working with the use of mineral acids, 142, 143
Couch, broken the 93
  growing, the, 93
  wet, the, 92
  young, the, 93
Crushing mill for malt, 109, 110

Damsons, 68
Daucus, the, 67
Dead periods, 226
  preparation of yeast with the avoidance of, 242
De Latour on fermentation 210
Delbruck, mash filter of, the, 188, 189
  on foaming fermentation 276, 277
  on pure yeast culture, 217
Denaturing of alcohol, the, 343-352
  the purpose of, 343
  regulations, United States, 344, 345
  regulations, Germany, 345-348
  regulations, England, 348
  regulations, France, 348-352
  regulations, Sweden, 353
Dephlegmation, 297-300
  compound distillation, rectification, and, 300-316
Dephlegmator, important rules regarding the, 298
  the modern, 309-313
  theory of the 297
  Verehow's, 310, 311
  Wagener's 312 313
Deutz vaporizer, the, 364-366
Dextrin, 28
  and maltose, quantitative determination of, in the mash, 195-197
Dextrin, separate determination of, in the mash, 196, 197
  change of starch to 28
  proportional quantity of, 27
Dextrins, conversion of starch into, 28
  fermentation of, 28
Dextrose, 19, 230
  Allihn's table for determining the, from the reduced copper, 198-200
Dhurra, 64
Diastase, 19, 33-36
  action of, upon starch, 30, 31
  composition of, 35
  effect of the temperature upon, 35
  kind of sugar formed by the action of, upon starch, 34
  maximum effect of, on gelatinized starch, 35
  stimulation of the power of, 36
Diastatic efficacy of malt, 100
Disintegration of the starch of the raw materials, and the preparation of mashes, 112-149
Distillation, 20
  and rectification, 300-316
  compound, 293-325
  products of, 300
  simple, 43, 296, 297
  simple, product obtained by, 300
Distillery, coal consumption of the, 184, 185
  power necessary to drive the machinery of the, 182-184
  water consumption of the 281
  yeast characteristics it should possess 223-225
Distilling apparatus, 300-319
  arrangement of the, 335-337
  cleaning the, 316, 317
  Coffey's, 304
  continuous, 303-316
  for the production of raw spirit, 304-309
  for the production of spirit directly from the mash, 315, 316
  general type of column, 304-307
  Ilges' 314, 315
  periodical, 300-303
  Pistorius', 301-303
  Savalle's, 304
  simple, 297
  two part, column, 307-309
Doeultz E., Groening's alcohol table amplified by, 294
Dresdener vaporizer, the, 368, 369
Drop culture, 214-215
Drying barley alterations in, 100
  preservation of malt by, 106-108
Dürr vaporizer, the, 367, 368

Eckert mashing and cooling apparatus, the, 168, 169
  potato washer, the, 112, 113
Efficiencies, comparative, of gasolene, kerosene and alcohol motors, 359-362

Effront's method of preserving yeast with fluoric acid, 248
Electricity, purification of alcohol by, 325
Ellenberger's, Venuleth and, mashing apparatus, 161
Embryo, growth of the, during germination, 88, 89
Emergency yeast, preparation of, 242, 243
Endogenous spore formation, 216
Engines, alcohol, efficiency of, 8 11, 359-362
  increasing use of internal combustion, 2, 3
  internal combustion, numbers in use 3
England, denaturing regulations in, 348
English method of mashing, the, 156-158
Enzymes, 32
  carbohydrate, 33
  carbohydrate, action of during germination, 87
  of greatest importance in distillation, the, 34 40
  proteolytic, 33
  proteolytic action of during germination, 87
Ether, 319
Erythro dextrin, 28
Ethyl alcohol, 42
Eurotium oryzae, 105
Examination of alcohol and alcoholic liquors for fusel oil, and other impurities, 317, 318
  of the mash after fermentation, 281-287
Exhauster the, 125-128

Fatty acids, volatile, effect of, on fermentation, 230
Fehling's solution, preparation of, 197
Feints 219
Felted malt, 98 99
Fermentation, 20, 204-235
  after-, 268, 269
  alcoholic, 204 235 266 293
  alcoholic as it is understood today, 208, 209
  alcoholic, by-products of, 44, 45
  alcoholic, products of, 11 14, 231-232
  chief, 267, 268
  checking of by butyric acid, 230
  cleanliness in 234
  definition of, 208
  development of heat during, 227, 228
  effect of nitrogenous acid on 229
  effect of volatile fatty acid on, 230
  effect of alkalies on 230
  effect of sulphurous acid on, 229
  exciters of, 212 216
  exciting mold fungi and bacteria, 226 227
  foaming, 275-278
  historical data of, 209 212
  in the yeast mash, 258, 259
  induction of, 19
Fermentation in practice, 266-292
  losses in, 287-288
  of beet juice, 159
  of dextrins 28
  of the mash, yield of alcohol from, 287-289
  of the yeast mash, determination of the degree of, 264
  periods, 266-269
  periods, value of longer, 275
  pre-, 266, 267
  products obtained by, 231, 232
  promotion of by lactic acid, 232, 233, 244 247
  regulation of the temperature during, 207
  substances capable of, 230
  substances injurious and favorable to, 229, 230
  vat cooling, movable, in, 269 273
Fermented mash, determination of the acidity of the, 285 286
  examination of the with the saccharometer, 281 285
  investigation of the 281 287
Fermented mashes distillation of alcohol from, 293 326
Fermenting room and fermenting vats, the, 278 280
  room construction of the, 278 279
  temperature cooling the mash to the, 204-208
  vats 279, 280
  vats, cooling apparatus for, 207
  vats, varnish for, 208
Ferments 19, 32-40
  chemical, 32
  organized, 32
Filter for filtering raw spirit through charcoal, 325
First runnings, 319
Fission fungi, 232
Flask, Carlsberg the, 218
  Pasteur the 218
Floor, malting, the, 84
Fluoric acid, preparation of yeast with, 248
Foaming fermentation, 275 278
Foreshots, 319
Formic acid 42
Foth's table for determining the apparent degree of fermentation and the alcohol content of mashes, 284
France, denaturing regulations in, 349-352
  statistics of alcohol production in, 105 106
Fresenius analysis of fruits and berries by, 68
Fructification of yeast cells, 215, 216
Fructose 230
Fruits, production of alcohol from, 68
  sugar content of, 68
Fuel, alcohol as advantages of, 6
  liquid, the demand for a cheap, 2
Fungi, fission, 232
  malt from, 105, 106
Fungus fermentation, 289-292
Furfurole, 318

- Fusel oil, 44, 317-319
  - determination of, 317, 318
  - detection of, 317, 318
  - method of removing, 318, 319
- Fusel oils, 44, 318

- Gasoline, insufficiency of the supply of, 4
- Germany, statistics of alcohol production in, 401-404
  - denaturing regulations in, 345-348
- Germination, 82, 83, 86-92
  - commencement of, 86
  - development of the grain during, 90-92
  - during long malting, 96-98
  - growth of the embryo during, 89
  - process of, the 86-92
  - respiration during, 89 90
  - temperatures for, 90
- Germs, development of the, 89
- Gigantic carrot, the, 67
- Glucase, 230
- Glucose, 230
  - and grape sugar, alcohol from, 160
- Glycerine, 45, 231
- Grain, 59-65
  - amides in, 87
  - respiration of, during germination, 89, 90
  - treatment of, in the Henze steamer, 132-149
  - treatment of, upon the malting floor, 92-94
- Grape sugar, 160, 230
  - and glucose, manufacture of alcohol from, 160
- Great Britain, denaturing regulations, 348
  - statistics of alcohol production in, 406
- Green corn stalks production of alcohol from, 67
  - malt, 106
  - malt, preparation of yeast from, 240-242
- Grist, the working of 139-141
- Groening's alcohol table, amplified by Doenitz, 294
  - as corrected by Sorel, 295
- Growing couch, the, 93

- Hampel mash clearing apparatus, the, 176, 177
  - mashing and cooling apparatus, the, 165, 166
- Hansen, investigations of, 210, 211, 215, 217
  - pure yeast culture of, 217
- Heat, development of, during fermentation, 227, 228
  - value of alcohol, the, 358
- Heating with alcohol 373-390
  - advantages of, 373 374
  - appliances for 377 390
  - economy of 374, 375
  - nature of the fuel in, 375-377
- Heckmann bell rectifying apparatus, the, 321, 322
- Heinzelmann on yeast mashing, 239, 240
- Henze steaming apparatus, the, 117-132
  - arrangement of, 117-120
  - blow-out devices of, 128-131
  - closures for, 122-125
  - devices used with, 125-132
  - size of, 122-123
  - table for estimating the size of, 122
  - treatment of grain in, 132-149
  - use of, 120-122
  - working corn in, 135-144
- Hermbstadt, investigations of 185
- Historical data of alcohol, 209-212
- Hesse's method of long malting, 96
  - vat cooler, 270
- Hintz-Göbel mash clearing apparatus, the 177, 178
- Hoppe-Seiler and Traube, theory of, 39
- Hollefreund steaming apparatus, 116
  - working corn in, 141
- Hop yeast preparation of, 242, 243
- House malt, the, 83-86
- Hydrometer, the, 286

- Ice, cooling with, 207, 208
  - quantity of required for cooling, 208
- Ilges' distilling apparatus, 314 315
- Illumination with alochol, 391-398
- Impurities in raw spirit, 318
- Instructions, regulations and, concerning denatured alcohol under the act of Congress of June 7, 1906, 416-505
- Invertase, 33
- Iodine, examination of starch with, 29, 30
  - solution test of the mash with the, 190-192

- Jerusalem artichoke, the, 67

- Kaminski vat cooler, the, 271
- Killing-Oppenheim process, the, 325
- Kiln-dried malt, 100, 107, 108
  - diastatic power of, 107
  - preparation of yeast from 242
- Kiln drying malt, method of, 107, 108
- Krocker's method for determining the starch of potatoes by specific gravity, 56, 57
- Kutzing on acetic acid fermentation, 210

- Lacquer for fermenting vats, 280
- Lactic acid, and volatile fatty acids, yeast preparation with, 250
  - technical, yeast preparation with, 248-250
  - favorable effect produced in the yeast mash by the, 232, 233
  - ferment, temperature favorable to the growth of, 234
  - fermentation, 232-234
  - races, 233
  - pure culture, 245
  - promotion of fermentation by, 232, 244
- Lamp, alcohol, the, 392-397
  - advantages of, 397, 398
- Leinhaas' mash clearing apparatus, 175

Lighting with alcohol, 391-398
Levulose, 230
Liebig's theory of fermentation, 210
Lindner's investigations, 217
    pure culture apparatus, 220-222
Lintner's method of producing soluble starch, 28
Lipase, 34
Liquid fuel, the demand for cheap, 2
Long malt, 94-98
    from oats, 104
    from rye and wheat, 102
Losses in fermentation, 287, 288

Maceration and diffusion, extraction of beet juice by, 159
Maercker, mode of preserving yeast, recommended by, 261
Maize, 61-63
    malt from, 100, 104, 105
    mashing with, 159
    starch granules of, 23, 24
Malt, 19
    air-dried, 106, 107
    air-dried, diastatic power of, 107
    and yeast centrifugal apparatus for the preparation of, 110
    comparison of the efficacy of the different varieties of 100
    composition of, 99, 203
    content of barley in, 99
    content of water in, 99
    crusher, 109, 110
    diastatic efficacy of, 100
    embryo, composition of the, 99
    felted, 98, 99
    for yeast, 237
    from corn 100 104, 105
    from fungi, 105, 106
    from maize, 100, 104, 105
    from oats, 100, 102 104
    from rye, 100-102
    from wheat, 100-102
    green, 106
    green, comminution of, 109-111
    green, preparation of yeast from, 240-242
    house, the 83
    house, arrangement of the, 83-86
    kiln dried, 100, 107, 108
    kiln-dried, diastatic power of 107
    kiln dried, composition of, 203
    kiln-dried preparation of yeast from, 242
    long, 94-98
    long, from oats, 104
    long, from rye and wheat, 102
    loss in efficacy of, by drying, 107
    material suitable for the preparation of, 70
    milk apparatus, 111
    preparation of, 69-111
    preparation of the best, barley for, 70-73
    quantities necessary for saccharization, 108, 109
    purpose of, in distillation, the, 69
    water content of 99
    well dried, qualities of, 108
    yield of, from barley, 99
Maltase, 33
Malted corn, working of, 143, 144
Malting, determination of the suitability of barley for, 70-73
    floor, the, 84
    floor, treatment of the steeped barley upon the, 85, 86, 92-94
    grain, 70-73
    important considerations in, 69
    long, duration of, 95, 98
    long, germination during, 96-98
    long, Hesse's method of, 96
    water, properties which it should possess, 73-75
Maltose, 19 151, 230
    and dextrin, quantitative determination of, in the mash, 195 197
    and dextrin, separate determination of, in the mash 196, 197
    and dextrin, proportional quantities of, 27
    Wein's table for determining the, 201, 202
Mandel's process of working corn with compressed air, 143
Manufacture, summary of the processes in spirit, 19 21
Manufactures, alcohol in the, 11, 12
Marienfelde alcohol motor the, 370 372
    vaporizer, the, 369, 370
Mash, air cooling of the, 204
    apparatus for the production of spirit directly from the, 315, 316
    clearing the, 173-182
    clearing the, advantages of, 174, 175
    clearing apparatus, 175-182
    clearing apparatus, choice of the, 182
    clearing apparatus of Bohm, the, 175, 176
    clearing apparatus of Hampel, the, 176, 177
    clearing apparatus of Hintz Gobel, the, 177, 178
    clearing apparatus of Leinhaas, the, 175
    clearing apparatus of Müller, the, 180, 181
    clearing apparatus of Paucksch, the, 178 180
    combined water and air cooling of the, 205
    contrivances for cooling the, with water 160-173
    cooling the, to the fermenting temperature 204-208
    determination of the content of acid in the, 193-195
    determination of the content of acid in the, apparatus for, 194
    determination of the total quantity of carbohydrates in the, 195-197
    examination of the sweet, 185-197
    examination of the, after fermentation, 281-287
    fermentated, examination of the, with the saccharometer, 281-285
    fermentated, determination of the acidity of the, 285, 286

Mash filter, Delbrück's, 188, 189
  from a mixture of potatoes and corn, 144
  mills, 131, 132
  principles employed in cooling the, 269
  products of the distillation of the, 300.
  quantitative determination of maltose and dextrin in the, 195 197
  quantity of ice required for cooling the, 208
  reviving the, with water, 274
  separate determination of maltose and dextrin in the, 196, 197
  sweet, use of ripe yeast for pitching the, 261, 262
  test of the, with the iodine solution, 190 192
  yeast coolers, 253, 256
  yeast, cooling the, 253
  yeast preparation of the, 236 240
  yeast souring temperature of the, 246
  yeast, sterilization of the, by heat, 251, 252
  yeast, Partenheimer's, 244
  yield of alcohol from the fermentation of the, 287-289
Mashes, alcoholic, fermentation of, 204-235
  clear, preparation of, 173 182
  examination of, with the saccharometer, 185 197
  from sacchariferous raw materials, 159, 160
  from sugar beets, preparation of, 159
  from molasses, dilution of, 160
  from molasses fermentation of, 160
  pitching temperature for, 258
  Steinheil's table for the correction of the specific gravity of and the content of extract in, 188
  with potatoes, 153-155
Mashing 150 182
  and cooling apparatus, Bohm's, 169-171
  and cooling apparatus, Eckert's, 168, 169
  and cooling apparatus, Hampel's, 165, 166
  and cooling apparatus, Pampe's, 166 167
  and cooling apparatus, Paucksch's, 163, 164
  and cooling apparatus, Wagener's, 164
  apparatus, 160-173, 239, 240
  apparatus, centrifugal, 172
  apparatus, Venuleth and Ellenberger's, 161
  apparatus, water cooled, 163-172
  apparatus without water-cooling, 161-163
  barley, rye, wheat, and oats, 156-159
  chemical processes in, 150-152
  chief aim of, the, 150
  cleanliness in, 153
Mashing, concentrated, advantages of, 273, 274
  corn, 159
  corn with the use of sulphurous acid, 134, 135
  English method of, the, 156 158
  in one period, 156
  in practice, 153 155
  in two periods, 156
  machine, Steel's preparatory, 157
  management of the operations of, 153 155
  oar, steam, the, 239
  principles to be considered in, 150-153
  process, Porion's, 158, 159
  purpose of the, 150
  raw materials table of the compositions of the best, 203
  saccharizing period in, the, 151
  temperature, choice of the, 151, 152
  vat, preparatory, the, 161, 162
Methyl alcohol 11
Mill, malt crushing, 109, 110
Millet 64
Mineral acids, working corn with, 142, 143
  yeast preparation with, 250, 251
Moisture in barley and malt, 99
Molasses, 66 67
  composition of 66
  constituents of 66
  mashing of 159, 160
  testing with Fehling's solution, 66
  yield from 66
  sugar in, 66
Mold fungi, fermentation exciting, 226, 227
Monilia candida, 39
Mother yeast, the 256, 257
  ripeness of, 259
  removal of, 260, 261
  quantities of, used, 260
  vessels for keeping the, 261
Motor, alcohol, the 362 372
Motors, alcohol, efficiency of, 8-11
  gasoline kerosene and alcohol, comparative efficiencies of, 359-362
Mucor erectus 226
  racemosus, 226
Muller mash clearing apparatus, the, 180, 181

Nägeli on starch, 24
Nematoid rot, 51
Nitrogenous acid effect of, upon fermentation, 229

Oar, steam mashing, the, 239
Oat malt, efficacy of, 100
  starch granules, 22-24
Oats, 63
  composition of, 64
  malt from, 100, 102-104
  starch granules of, 22-24
O'Sullivan researches of, 27
Oxydase, 34

Pampe's low pressure rectifying apparatus, 353-372

- Pampe's mashing and cooling apparatus, 166, 167
- Partenheimer's mash yeast without malt, 244
- Pasteur flask, the, 218
  - researches of, 210
- Paucksch mash clearing apparatus, 178-180
  - mashing and cooling apparatus, 163, 164
- Peptase, 36, 37
- Peptones, 88
- Periodically working distilling apparatus, 300-303
- Phytophtora rot, 51
- Piece, the, 93
- Pistorius' distilling apparatus, 301-303
- Pitching temperature, the, 261
  - temperature, cooling to the, 264
  - the sweet mash with ripe yeast, 261, 262
- Porion's mashing process, 158, 159
- Potato mashes, proportions of quantities used in the Henze apparatus, 122, 123
  - scale, 51
  - starch, granules of, 23, 24
  - washer, location of, 113
  - washer, the, 112-114
- Potatoes, 46-59
  - and corn, mash from a mixture of, 144
  - botanical and chemical characteristics of, 47-49
  - composition and qualities of, 46, 47
  - content of starch in, 47
  - constituents of, 47
  - determination of the starch of, by specific gravity, 52-57
  - determination of the dry substance in, 57
  - diseases of, 51, 52
  - dry, 58
  - dry substance in, 52
  - from seed, 46
  - frosted, 56
  - frozen, determination of the starch in, 55, 56
  - frozen, steaming of, 121, 122
  - hoister for, 113
  - investigation of, with regard to starch, 52-57
  - mashes with, 153-155
  - mashing of, the, 153-155
  - mashing of the, mixed with rye, wheat or barley, 148, 149
  - nitrogen in, 49
  - salt test for the starch of, the, 56, 57
  - steaming of, the, 114-117, 120-122
  - steaming of frozen or wet-rotted, the, 121, 122
  - steaming of, rich in starch, the, 121
  - steaming of, under normal conditions, the, 120, 121
  - sugar in, the, 49
  - table for the determination of the starch of, 55
  - washing of, the, 112-114
  - working of, the, 112-132
- Potatoes, yield of, the, 46
- Pre-fermentation, 266, 267
- Power from alcohol, 353, 372
  - necessary to drive the machinery of the distillery, 182-184
- Prolification of yeast cells, 212-215
- Propionic acid, 42
- Propyl alcohol, 44, 318
- Protoplasm, 212
- Prune juice, 325
- Purification of alcohol, 317-325
  - with chemicals, 325

- Raw materials, 18
  - composition of the best mashing, 203
  - sacchariferous, 65-68
  - starchy, 46-65
  - steaming of, the, 112-150
- Rectification, distillation and, 293-325
  - and purification of alcohol, 20, 317-325
  - apparatus for, 319-324
  - compound distillation and dephlegmation, 300-316
  - substances used during, 324-325
- Rectifier, bell, the, 298, 299
  - tube, the, 298, 299
- Rectifying apparatus, Heckmann's, 321, 322
  - apparatus, Pampe's low-pressure, 322-324
  - apparatus, Savalle's, 319-321
  - column, 299
  - spirits, chief object in, 317
- Refined spirit automaton, Ilges', 314, 315
- Regeneration of charcoal, the, 325
- Regulations and instructions concerning denatured alcohol under the Act of Congress of June 7, 1906, 416-505
- Reimann's potato scale, 52-54
  - potato scale precautions with, 54-56
- Reinke's method of yeast preservation, 261
- Respiration of germinating grain, 89, 90
- Reviving the mash with water, 274
- Rhizoctonia rot, 51
- Rice, 64
  - composition of, 64
  - production of alcohol from, 64
- Ripe yeast, 259
- Rye, 60
  - composition of, 60
  - malt, 100-102
  - malt, efficacy of, 100
  - malt, mashing of, 156-159
  - starch granules of, 22, 23
  - working of the, 145-149
  - working mixtures of, and potatoes, 148, 149
  - working uncrushed, at ordinary pressure, 145, 146
  - working uncrushed, under high pressure, 147, 148

- Sacchariferous raw materials, 21, 65-68
- Saccharization, 19, 69

- Saccharization, malt necessary for, 108, 109
- Saccharizing period in mashing, the 154
- Saccharometer, the, 186-187
  - determination of specific gravity by means of 185-187
  - examination of the fermented mash with the, 281-285
  - examination of mashes with the, 185-190
- Saccharometry, 185-190
- Saccharomyces, 212
  - cerevisiae, 212-225
  - spores of, 212-215
- Saccharose, 230
- Saint John's bread extract, 325
- Salt test for potatoes, the, 56, 57
- Savalle's rectifying apparatus, 319, 321
- Scale on potatoes, 51
  - Riemann's potato, 52-54
  - Riemann's potato, precautions with, 54-56
- Scheibner comminuting cone, the, 128
- Schizomycetes, in the distillery, 232-235
- Schwann on fermentation, 210
- Setting the yeast, 256-258
  - temperatures for, 258
- Simple distillation, 296, 297
- Soluble starch, 28
- Sorel, investigation of Groening's alcohol table by, 293-295
  - Groening's table as corrected by, 295
- Sorghum 67
- Souring, technical acids to replace, 247-251
  - the yeast mash, 244-247
- Spore formation, endogenous, 215
- Specific gravity, changes in, due to different temperatures, 187
  - definition of 52
  - determination of, by means of the saccharometer, 185, 186
  - determination of the starch in potatoes by, 52-54
  - of mixtures of alcohol and water, table of the, 328
  - table for comparing the, of sugar solutions with their sugar content, according to Balling, 186
  - table for the determination of starch in potatoes from the, 55
- Specifications for methyl alcohol and benzine submitted for approval as denaturing materials in the United States, 411-415
- Spent wash, the, 21, 337-341
  - composition of the, 337-339
  - nutritive value of the, 339
  - utilization of the, 339-341
- Spirit, clean, 319
  - of wine, 41-44
  - filtering of, through charcoal, the, 324, 325
  - raw, constituents of 318
  - raw, distilling apparatus for the production of, 303-309
  - raw, filter for filtering through of charcoal, 325
  - raw, apparatus for the production of, directly from the mash, 315, 316
- Spirits, 300
  - chief object in rectifying, 317
- Spores of saccharomyces cerevisiae, 212-215
- Stahl on fermentation, 209
- Starch, 22-31
  - behavior of, relative to water, 25-27
  - behavior of, under high pressure, 27
  - behavior of, with respect to acids and diastase, 30, 31
  - change of, to dextrin, 28
  - characteristics of, 25
  - chemical composition of, 24, 25
  - conversion of, in the plant, 87
  - conversion of, into soluble sugar, 28
  - determination of, in frosted potatoes, 56
  - disintegration of and preparation of mashes, 150-182
  - formation of, 25
  - forms of, 22
  - gelatinized, effect of diastase on, 27
  - gelatinizing temperatures of, 26
  - granules, 22
  - granules of corn, 23, 24
  - granules of potatoes, 22
  - granules of rye, wheat, and barley, 22, 23
  - in potatoes, content of, 52-54
  - in potatoes, determination of the, by specific gravity, 52-57
  - in potatoes, table for the determination of the content of 55
  - raw materials containing, 46-65
  - reactions of, 28-30
  - reagent for, 29, 30
  - soluble, 28
  - soluble, Lintner's method of producing, 28
  - theoretical and practical yield of alcohol from the, 41, 288, 289
- Statistics of alcohol production, 399-407
  - in Belgium, 407
  - in France, 405-406
  - in Germany, 401-404
  - in Great Britain, 406
  - in United States, 399, 400
- Steam jet exhauster, the, 125-128
  - mashing car, the, 329
- Steaming, 19
  - raw materials, 112-150
  - apparatus, Bohm, the, 117
  - apparatus, distribution of steam in, 136, 137
  - apparatus, Henze, the, 117-132
  - apparatus, Henze, arrangement of the, 117-120
  - apparatus, Henze, blow-out devices of the, 128-131
  - apparatus, Henze, closures of the, 122-125
  - apparatus, Henze the, devices used with the, 125-132

Steaming apparatus, Henze, size of the, 122-123
  apparatus, Henze, table for estimating the size of the, 122
  apparatus, high pressure, 117-125
  apparatus, Hollefreund, the, 116
  apparatus, treatment of grain in the, 132-149
  apparatus, use of the, 120-122
  apparatus, working corn in the, 132-144
  corn, 132-144
  corn in the steam vat, 132, 133
  materials other than potatoes, 132-150
  potatoes, 114-117, 120-122
  potatoes at ordinary pressure, 115
  potatoes under high pressure, 116, 117
Steel's preparatory mashing machine, 157
Steeped barley, tests for, 80, 81
Steeping, admission of air during, 81, 82
  barley, 77-83
  time required for, 77-81
  vats, 77-78
Steinheil's table for the correction of the specific gravity and content of extract in mashes at various temperatures, 188
Sterile barley grains, 79
Still, Coffey's, 304
  Pistorius' 301-303
  Savalle's, 304
  simple, the, 297
Storage of potatoes, the, 50, 51
Succinic acid, 45
Sugar beets, 65
  determination of sugar in, 65
  preparation of mashes from, 159
  content of sugar in, 65
Sugar content of beet juice, 65
Sugar, kind of, formed by the action of diastase upon starch, 34
  raw materials containing, 21, 65-68
  conversion of, soluble starch into, 28
  splitting up of, the, 41
  yield of alcohol from the, 41
Sulphuric acid, working corn with, 142, 143
Sulphurous acid, working corn with, 134, 135
Sulpharous and sulphuric acids, effect of, on fermentation, 229
Summary of the processes of spirit manufacture, a, 19-21
Sweden, denaturing regulations in, 352
Swimmers for ice-cooling, 208

Table, Allihn's, for determining the dextrose from the reduced copper, 198-200
Table, Balling's, for comparing the specific gravities of sugar solutions with their sugar contents, 186
  for determining the content of starch in potatoes from the specific gravity, 55
Table for determining the true strength of alcohol at 60 degrees F., from the apparent strengths at different degrees of temperature, 329-334
  for estimating the size of the Henze steamer, 122
  Foth's, for determining the apparent degree of fermentation and the alcohol content of mashes, 284
  Groening's alcohol, as amplified by Doenitz, 294
  Groening's alcohol, as corrected by Sorel, 295
  of specific gravities of mixtures of alcohol and water, and the corresponding per cent by volume and by weight of alcohol, 328
Table of the compositions of the best mashing raw materials, 203
  Steinheil's, for the correction of the specific gravity and content of extract in mashes at various temperatures, 188
  Wein's, for determining the maltose, 201, 202
Tax-free alcohol, benefits of, to agriculture, 14, 15
  in the past, 12-14
Technical acids, to replace souring, 247-251
Temperature, regulation of, during fermentation, the, 207
Tests for the sweet mash, 190-197
Top yeast, 223
Traube and Hoppe-Seiler, the theory of, 39
Tube rectifier, the, 298, 299

United States denaturing regulations, 314, 345, 416-505
  statistics of alcohol production in, 399, 400
  specifications for methyl alcohol and benzine submitted for approval as denaturing material in, 411-415

Vacuoles, 212
Valentinus, Basilius, 209
Van Helmont on fermentation, 209
Vaporizers for alcohol motors, 303-320
Varnish for fermenting vats, 280
Vat cooler, Hesse's, 270
  cooler, Kaminski's, 271
  cooling, movable, 269-275
Vats, fermenting, 279, 280
  forms of, 280
  cooling apparatus for, 205-207
  mashing, 160-173
  mashing, capacity of, 172
  preparatory mash, 161, 162
  steam, working corn in, 132, 133
  steeping, 77, 78
  yeast mashing, 239, 240
Venuleth and Ellenberger's cooler, 161
Verchow's dephlegmator, 310, 311

Vogel, method of detecting fusel oil proposed by, 317
Volatile fatty acids, effect of, on fermentation, 230

Wagener, blow-out valve, the, 130
  dephlegmator, the, 312, 313
  mashing and cooling apparatus, the, 164
Wash, spent, the, 43, 337-341
Washer for potatoes, Eckert, the, 112, 113
Water and air cooling, combined, 205
  boiling point of, 42
  consumption of the distillery, 281
  contrivances for cooling the mash with, 160-173
  for malting, 73-75
  in barley, 99
  in malt, 99
Wein's table for determining the maltose, 201, 202
Wet couch, the, 92
Wheat, 63, 64
  malt, 100-102
  malt, efficacy of, 100
  mashing of, the, 156-159
  starch, granules of, 22, 23
Whisky, 300
Wines, low, 300
Wood, alcohol from, 41
Worts, clear, chief advantages of preparing, 158
  clear, yield of alcohol from, 158
  preparation of, 156-158

Yeast, 19, 212-216
  acidity of, the determination of the, 264, 265
  Bau's method of distinguishing top and bottom, 223
  brewer's, 225
  brewer's bottom, 223
  brewer's top, 223
  cells, fructification of, 215, 216
  cells, growth of, 212-216
  cells, prolification of, 212-215
  cells, propagation of, 212-216
  chamber, the, 246
  chemical composition of, 228
  cooling coil, 255
  culture, pure, 19, 216-222
  culture, pure, natural, 225
  dead periods in the preparation of, 226
  degree of fermentation of, the determination of the, 265
  distillery, characteristics it should possess, 223-225
  emergency, preparation of, 242-243
  hop, preparation of, 243, 244
  investigation of the, 264, 265
  mash, 19, 236
  mash, preparation of, 236-240
  mash apparatus, 239
  mash coolers, 253-256
  mash, cooling of the, 253-256
Yeast mash, final sterilizing temperature of the, 237, 238, 251, 252
  mash, malt for, 237
  mash, object of preparing a, rich in nutrients, 237
  mash, setting the, 256-258
  mash, sour, cooling the, 253-256
  mash, souring of the, 232-235, 244-247
  mash, souring temperatures of the, 246
  mash, sterilization of the, with heat, 237, 238, 251, 252
  mashing vats, 239
  material, concentration of, 237
  material, temperatures for mashing the, 237
  mother, 256, 257
  mother, quantities of, used, 260
  mother, removal of the, 260, 261
  mother, vessels for keeping the, 261
  preparation, Bauer's method of, 251
  preparation of, the, 236-266
  preparation with avoidance of dead periods, 242
  preparation with fluoric acid 248
  preparation with green malt, 240-242
  preparation with kiln-dried malt, 242
  preparation with lactic acid and volatile fatty acids, 250
  preparation with mineral acids, 250, 251
  preparation with Partenheimer's mash, 244
  preparation with technical lactic acid, 248-250
  preparation, special directions for, 262-264
  preservation of the, 261
  Race II, 215
  Race XII, 217
  races, 222-226
  races, developed by cultivation, 216-222
  ripe, setting with, 256-258
  ripe, use of, for pitching the sweet mash, 261, 262
  souring technical acids to replace, 247-251
  special directions for preparing, 262-264
  substances suitable for the nutrition of, 228, 229
  temperature for setting with, the, 258-261
  the exciter of fermentation, 212-216
  top, 223
  vats, 239
  when ripe, 259
  wild races of, 215
Yield of alcohol in practice, 287-289
Young couch, the, 93

Zymase, 34, 37-40

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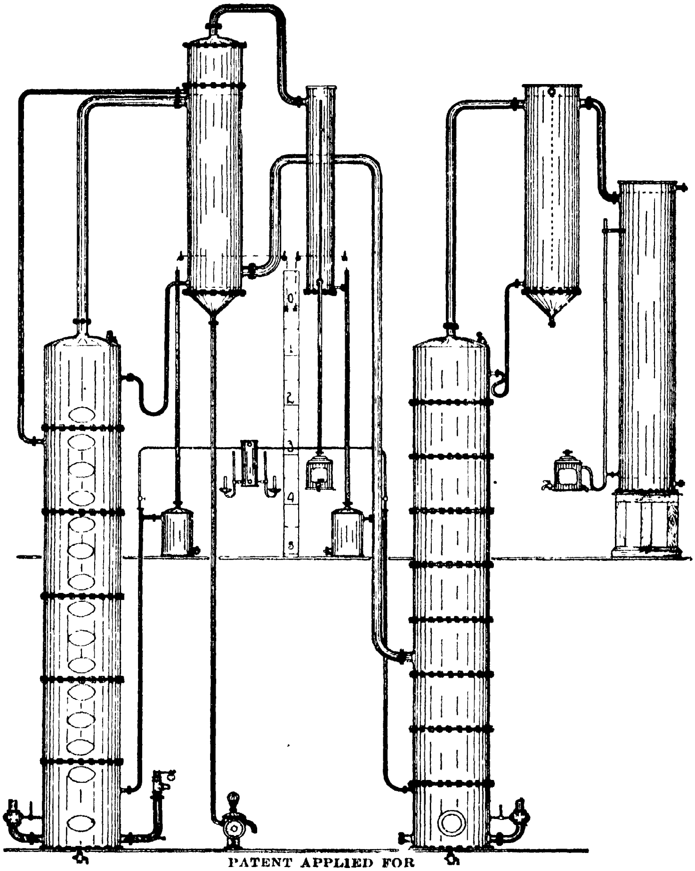

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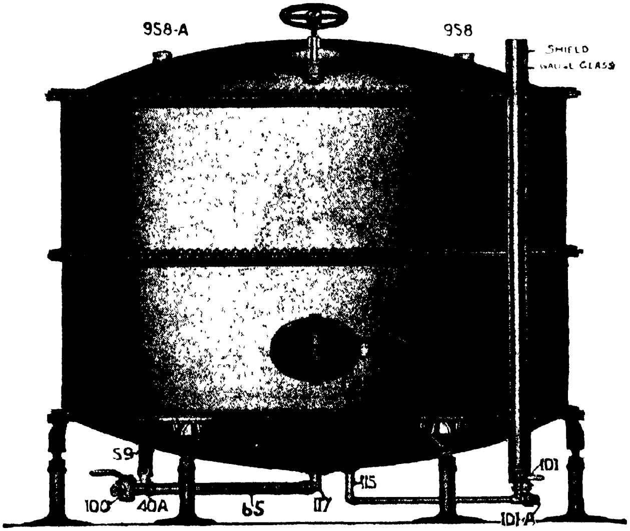

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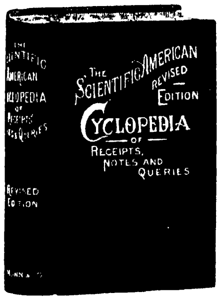
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